Journal

WATER POLLUTION CONTROL FEDERATION

FORMERLY SEWAGE AND INDUSTRIAL WASTES

Special Features

Whey Wastes in Lagoons—Maloney et al.

Detergents and Digestion—Hernandez and Bloodgood

Sludge Incineration—Sawyer and Kahn

Petrochemical Wastes—Malaney

Phosphorus Toxicity—Isom

Operator's Corner

Operator's Manual, Deeds and Data

1960 Meeting Report

1960 ANNUAL INDEX

DECEMBER 1960

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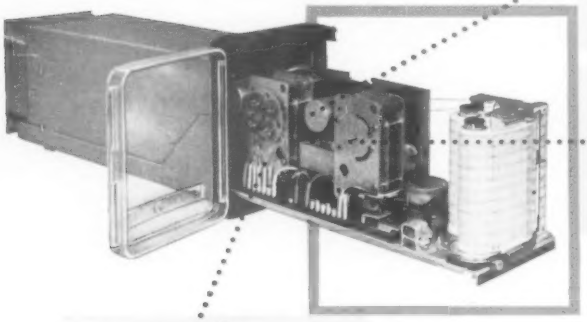
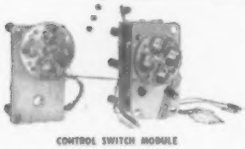


POWER SUPPLY MODULE

POWER POSITIONER MODULE



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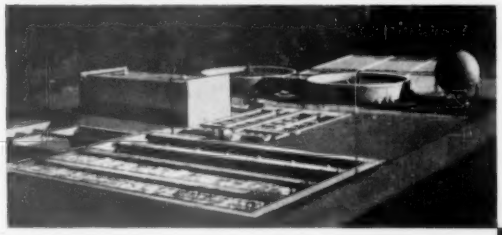

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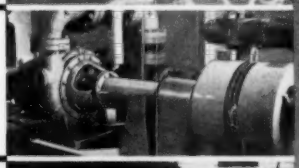

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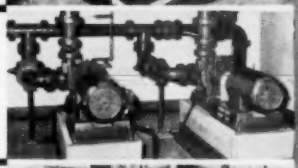

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Volume 32 December 1960 Number 12

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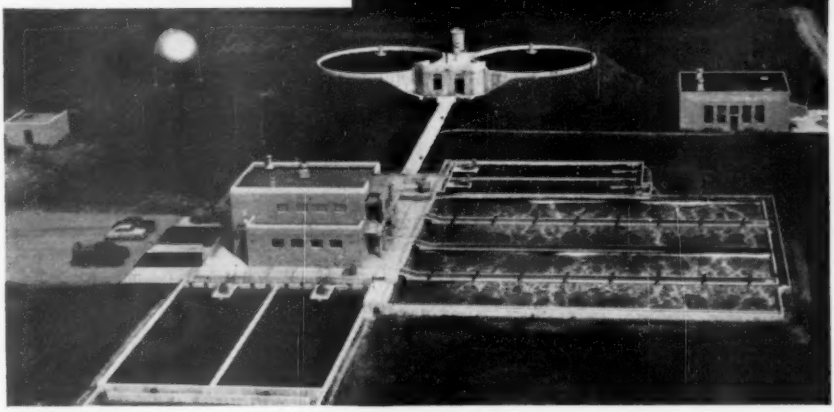

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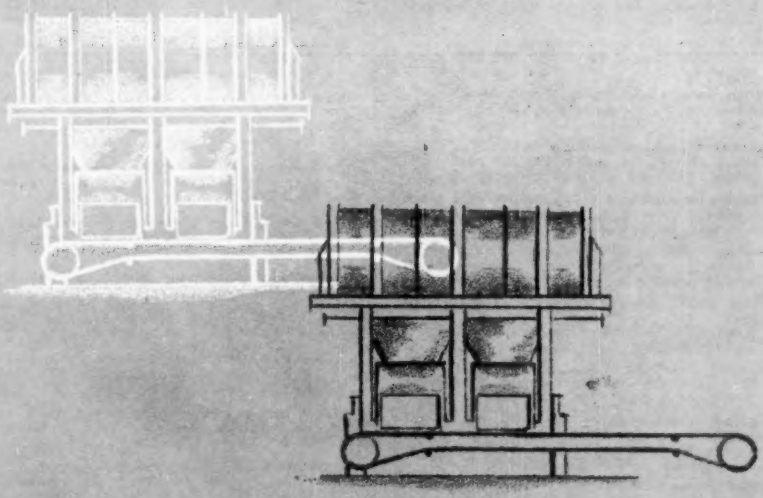

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Association *	*Date*	*Place*
New York	Jan. 18–20, 1961	Park Sheraton Hotel, New York City
Utah	Feb. 6–7	University of Utah, Salt Lake City
Puerto Rico	Feb. 24	Condado Beach Hotel, Santurce
ISP, South African Branch (England)	Mar. 6–10	Muizenberg Pavilion, Capetown, South Africa
Mississippi	Mar. 10	Robert E. Lee Hotel, Jackson
Texas	Mar. 12–17	Texas A & M, Student Center, College Station
New Jersey	Mar. 15–17	Traymore Hotel, Atlantic City
Arkansas	Mar. 19–22	Marion Hotel, Little Rock
West Virginia	Apr. 6–7	West Virginia Hotel, Bluefield
Kansas	Apr. 12–14	Baker Hotel, Hutchinson
Arizona	Apr. 20–22	San Marcus Hotel, Chandler
California	Apr. 26–29	Hotel Miramar, Santa Monica
Virginia	May 9	Hotel Chamberlain, Old Point Comfort
Alabama	June 5–7	University of Alabama, Tuscaloosa
Central States	June 7–9	Leland Hotel, Springfield, Ill.
Iowa	June 7–9	The New Inn, Okoboji

* See preceding left-hand page for full name.

THIRTY-FOURTH ANNUAL MEETING

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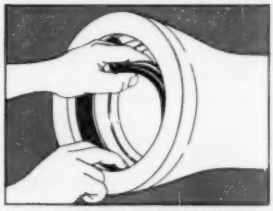
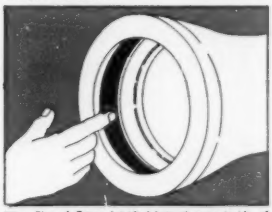
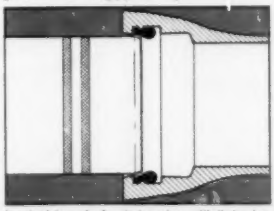


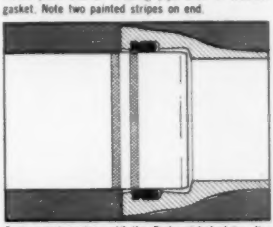
Insert gasket with groove over bead in gasket seat . . . a simple hand operation.



Wipe film of Tyton Joint® lubricant over inside of gasket. Your receiving pipe is ready.



Insert plain end of entering pipe until it touches gasket. Note two painted stripes on end.



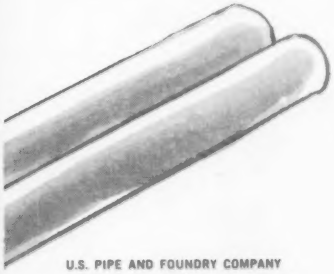
Push entering pipe until the first painted stripe disappears and the second stripe is approximately flush with bell face. The joint is sealed . . . bottle-tight, permanently! The job's done . . . . fast, efficiently, economically. Could anything be simpler?

almost as easy!

In their enthusiasm our hillbilly pals sometimes exaggerate.

Tyton Joint® pipe isn't quite as easy to install as falling off a log. But almost! One simple accessory and you're in business! No bell holes. No nuts, bolts, pots or ladles. Fewer weather delays, too. Tyton® can be installed in rain or wet trench, if need be. And even inexperienced crews can lay it.

Want more working days, less time, trouble in the trench? Tyton Joint pipe is your answer. Get the facts. Call or write today.



U.S. PIPE AND FOUNDRY COMPANY
General Office: Birmingham 2, Alabama

A Wholly Integrated Producer from Mines and Blast Furnaces to Finished Pipe

INDUSTRIAL SERVICE CAST IRON

The City of New Albany, Indiana, recently placed in operation a single plant which combines both mixed refuse and sewage sludge disposal functions. The installation of the C-E Incinerator Stoker and the C-E Raymond Flash Drying System at this same site enables New Albany to benefit from the economies inherent in a dual purpose plant.

Two C-E Incinerator Stokers with a daily capacity of 80 tons each, reduce refuse to a sterile ash that is free from clinkers and suitable for use as a sanitary land fill. "No-cost" Btu's from the burning refuse are used by the C-E Raymond Flash Drying System for drying the sludge. The utilization of this heat eliminates all auxiliary fuel requirements.

Primary sludge filter cake is reduced to approximately 8 per cent moisture content in the C-E Raymond Flash Drying System. The dried product can be sold for use as a soil conditioner to help defray plant operating expenses, with any excess being burned in the refuse incinerator.

Each of these C-E systems has been service-proved in installations large and small, and the combination furnishes a dependable and economical solution to a community's sewage-refuse disposal problems. Your nearest C-E office has more information readily available to you or your consultants.

New Albany operates combined mixed refuse and sewage sludge disposal facilities at same plant site

The Municipal Sewage Treatment and Incinerator Plant at the City of New Albany, Indiana, contains the C-E Raymond Flash Drying System and two C-E Incinerator Stokers.

Consulting Engineers:
Consoer, Townsend & Associates, Chicago.

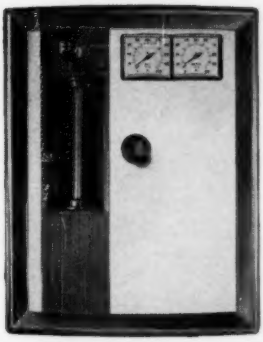
Contractors:
Fruin-Colnon Contracting Company and C&C Construction Company (a joint venture), Fort Wayne, Indiana.

COMBUSTION C-E ENGINEERING

Raymond Division: 427 West Randolph Street, Chicago, Ill.
Eastern Office: 200 Madison Avenue, New York 16, N. Y.
Western Office: 615 South Flower Street, Los Angeles 17, Calif.
CANADA: Combustion Engineering-Superheater Ltd.

C-293A

All Types of Steam Generating, Fuel Burning and Related Equipment; Nuclear Reactors; Paper Mill Equipment; Pulverizers; Flash Drying Systems; Pressure Vessels; Soil Pipe



This, believe it or not, is a wall mounted chlorinator. Its attractive appearance is our way of showing how proud we are of the advanced operating parts hidden behind the front panel. For example: This is the first wall mounted chlorinator ever to feature a single stack regulator. Simple, compact appearance belies the fact that it can handle up to 200 pounds per day of chlorine more accurately, dependably, and safely than any other chlorinator with the single exception of its big brothers. It is so completely corrosion-proof in the right places that we have little hope of ever selling replacement units. In short, we have never been happier with any product than we are with the new Series 3600 chlorinators .

Should you wish to order one of these beauties sight-unseen, on our say-so, we can deliver immediately from warehouse stocks across the country. If not, your local F&P field office will gladly demonstrate the 3600 Series at your plant, at your convenience. Call for an appointment. Or, write for complete information in Bulletin 70C3600. Fischer & Porter Company, 1220 Fischer Road, Warminster, Pa.

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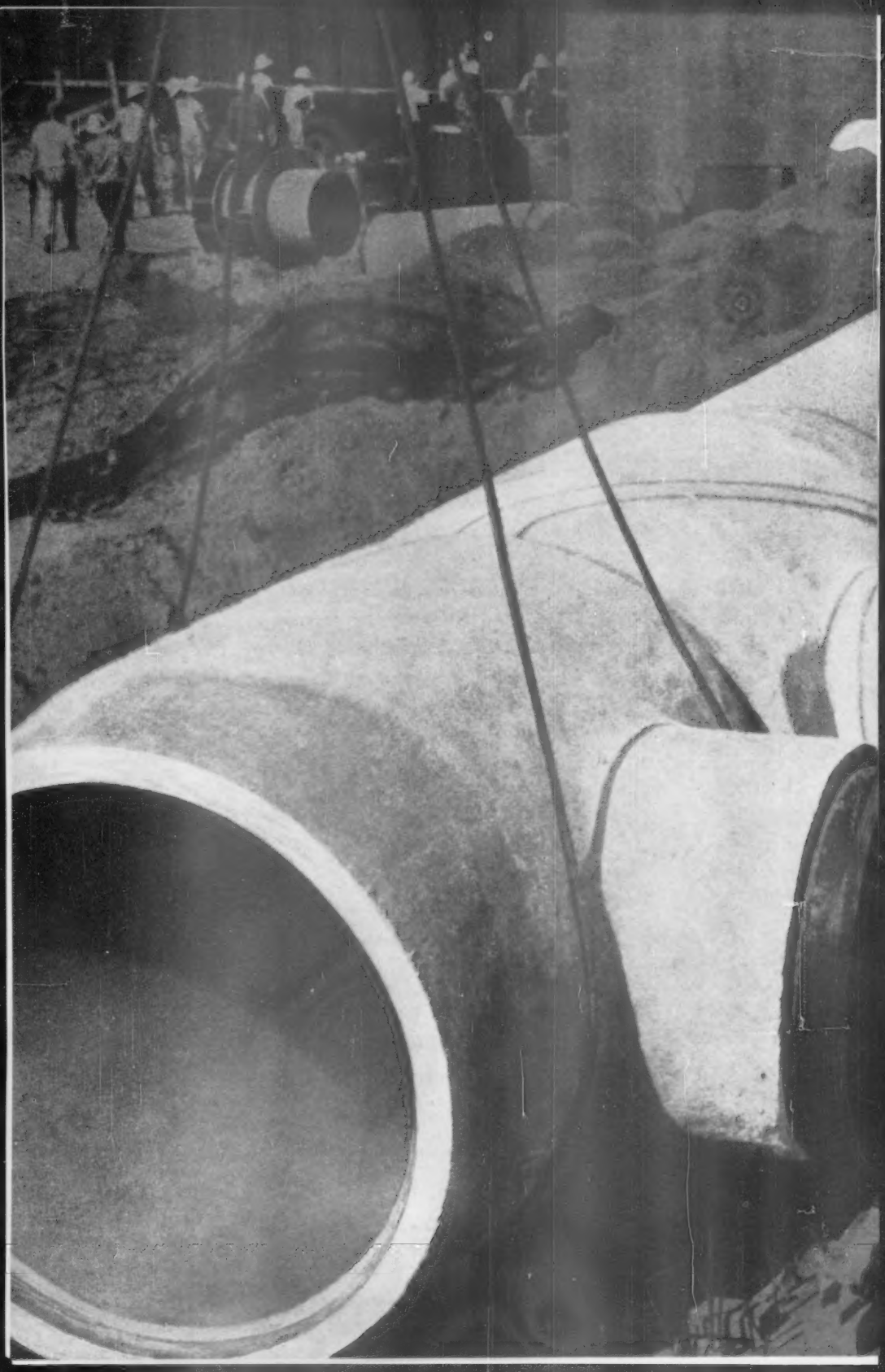


Concrete Pressure Pipe...

FOR RELIABLE PLANT PIPING

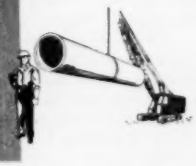
In congested plant areas housing vital and costly equipment, major piping materials must, above all, be reliable. Conclusive evidence of concrete pressure pipe's reliability lies in its unexcelled record for durability, trouble-free service and exceptional safety.

Plant piping must also be adaptable. The tailor-made characteristics inherent in concrete pressure pipe design make it an ideal material to meet the complexities of accurate entry into structures, and of precise juncture with other types of pipe and fittings within the limited confines of plant buildings.

Dependable, maintenance-free, and with sustained high carrying capacity, concrete pressure pipe assures reliable plant piping, whether for water or sewage treatment plants, for industrial supply lines, or for cooling or process water systems.

WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe



AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

228 North LaSalle Street, Chicago 1, Illinois

You can thank Johns-Manville's patented Ring-Tite® Joint which cuts ground water infiltration to a minimum. It's exclusive on *Transite®, the white sewer pipe.*

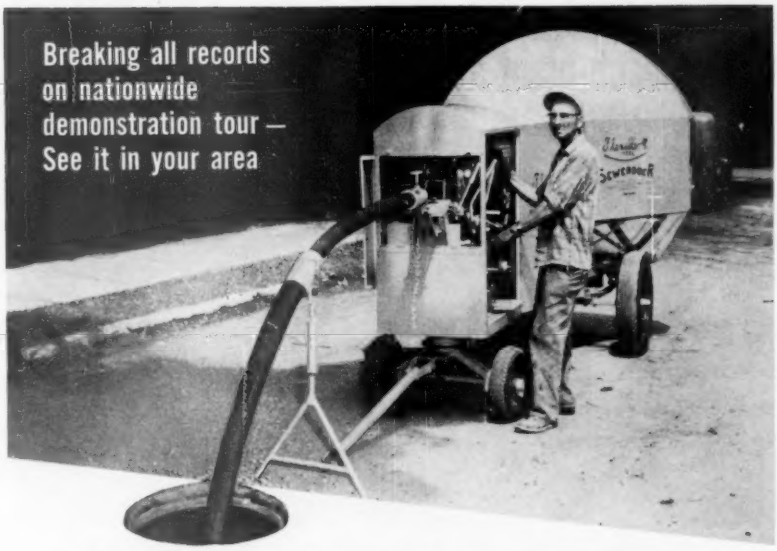
On a recent sewer project, specifications called for an extremely exacting infiltration test. What was the outcome? At final inspection, infiltration in the Transite line was 80% *less* than specification. What does this mean? Important savings! Volume of sewage to be treated is kept to a minimum . . . treatment plant operates as designed. The plant's reserve is conserved for future service.

Transite, made of tough, durable asbestos and cement, with its tight joints, offers many other savings. The long, light-weight lengths and sure coupling methods reduce trenching and installation costs. Transite's low coefficient of friction means faster flow and shallower trenches. Preventive maintenance with Transite will save you thousands of dollars.

Take it from Hartley—Transite can provide important economies in all sewer projects. Get all the details on Transite, the white sewer pipe. Send for your facts and data book today! Write Johns-Manville, Box 14, JW-1, New York 16, N. Y. In Canada: Port Credit, Ontario.

JOHNS-MANVILLE
TRANSITE PIPE

JM



SeweRodeR cleans far more sewer per man . . . per day . . . per dollar!

Public officials concerned with greater efficiency and upgrading working conditions in the Sewer Department will want to see a SeweRodeR demonstration when the team comes to their area. They'll see how one operator can rod from manhole to manhole non-stop, reaming out sludge and obstructions and restoring free flow in a matter of minutes. They'll see "case histories" showing the SeweRodeR can save up to $264 per mile in cleaning costs, and pay for itself in six months!

They'll like these exclusive advantages: positive chain and dog non-slip rod drive; audible safety clutch to protect tools, pipe and machine; push-pull power from 4 to 4,000 lbs., instantly reversible; ability to work water-filled manholes; and many more.

FLEXIBLE INC.

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3787 Durango Ave., Los Angeles 34, Calif.
1005 Spencerville Road, Lima, Ohio

HOW YOU CAN SEE **SeweRodeR** IN ACTION

Write for date of demonstration in your area. We are making arrangements in many cities and will notify you well in advance. Be prepared to compare your present sewer cleaning methods and costs with SeweRodeR. You may discover an entirely new approach to saving important budget money!

Rodney Hunt gates of tough Everdur withstand bleach-plant acid and pulp-mill wastes

Settling tanks of one of the first industrial waste-treatment plants in the paper industry at the Covington, Va., plant of West Virginia Pulp and Paper Co. Everdur was specified for mixing-chamber gates to resist corrosion by bleach-plant acids and pulp-mill wastes.

One of a pair of mixing-chamber gates fabricated of Everdur, each 48" wide by 54" high. The slide is a sheet of Everdur, reinforced by Everdur angles braze-welded in place. Frame and 2" stem also of Everdur.

Resists corrosion. Sewage treatment and waterworks equipment of Everdur* has been in service without replacement for 20 years and longer.

Toughness. Everdur also possesses high strength and resistance to wear and abrasion – so that engineers can use lighter weight wrought material in their designs.

Readily fabricated. Alloys of Everdur are available for hot or cold working, welding, free machining, forging and casting – and can be obtained in plates, sheets, rods, bars, angles, channels, tees, I-beams, wire, tubes, electrical conduit and casting ingots.

Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment" – or for technical help in selecting the correct material for your job. Address: Anaconda American Brass Co., Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

*Reg. U. S. Pat. Off. 5713IL

EVERDUR Anaconda's family of Copper-Silicon Alloys

ANACONDA AMERICAN BRASS COMPANY

STRONG · WORKABLE · WELDABLE · CORROSION-RESISTANT

FLUIDICS* AT WORK

How to increase aeration capacity without adding new tankage

Here is the new activated sludge system at York, Pa. Sewer Authority. Plant capacity is higher than ever before, yet not a cent has been spent for new basins.

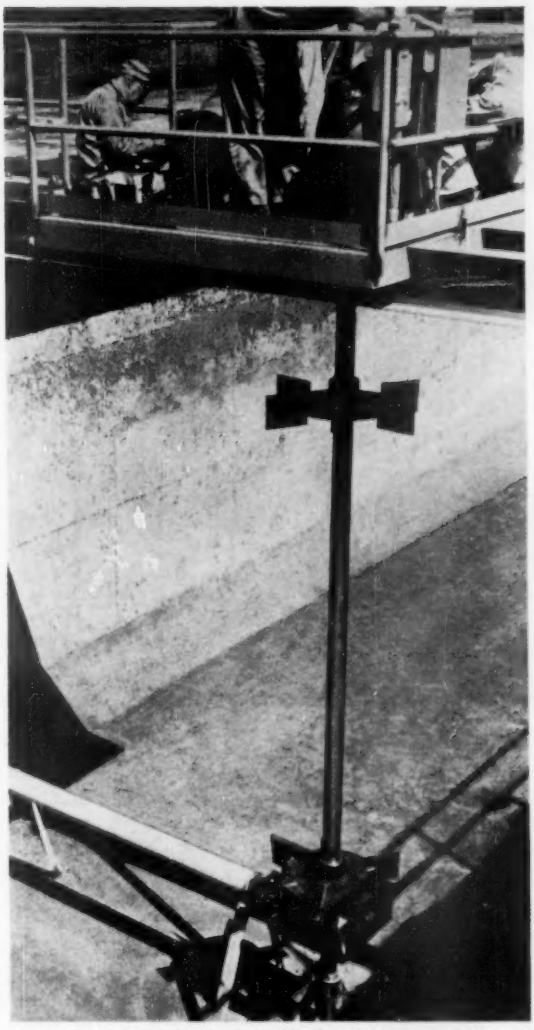
Four Permutit® Permaerators make up the heart of the system. The unit you see being installed is capable of transferring 115 lb. of oxygen per hour with a compressed air flow of only 420 cfm.

High efficiencies of this type are possible by utilizing atmospheric air entrained by the upper turbine of the Permaerator. In addition, the upper turbine redisperses compressed air released from a sparge ring beneath the lower turbine.

Albright & Friel, the consulting engineers, recommended Permutit Permaerators because of their high efficiency, rugged construction, and low initial cost. By the installation of four Permaerators, the system's ability to handle higher hydraulic and biological loadings was significantly increased. Since Permaerators are adaptable to old as well as new basins, this increase in treatment capacity was achieved without construction of any additional tankage.

What York has done, you too can accomplish. If you need to increase the capacity of your activated sludge plant with a minimum of capital expenditure, consider the Permutit Permaerator. For further information, write for Bulletin 4619. Permutit Division, Dept. JWP-120, 50 W. 44th Street, New York 36, N. Y.

*FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.



Twin-turbined unit being installed here is one of four Permutit Permaerators now in use at York, Pa.—one in each of two aeration tanks, and two in the return sludge stabilization tank.

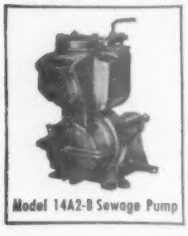
PFAUDLER PERMUTIT INC.
Specialists in FLUIDICS . . . the science of fluid processes

End Plate off

Towel out

End Plate on

"Towels can jam the works, but good!" says Cecil Kent, owner, Sanitation Service Company, Jacksonville, Florida. "I've had 'em clog conventional pumps so bad, it meant a shutdown from two hours to two days.


Model 14A2-B Sewage Pump

"That's why I've standardized on Gorman-Rupp sewage pumps. And what a difference! Fewer shutdowns . . . clogging cleared in just three to fifteen minutes! This cuts average maintenance costs from $120 to only $12 per pump per year. On my 21 Gorman-Rupp pump installations, that adds up to a whopping big saving. Over $2200 a year on parts, packing, materials, and labor.

"Sure, I had a problem—but no more!"

Thrifty, trouble-free, self-priming Gorman-Rupp sewage pumps—2″, 3″, 4″ or 6″ sizes—can be connected to your power or ordered complete with power units. Write for complete specifications.

THE GORMAN-RUPP COMPANY

305 Bowman Street **Mansfield, Ohio**

Gorman-Rupp of Canada, Ltd., St. Thomas, Ontario

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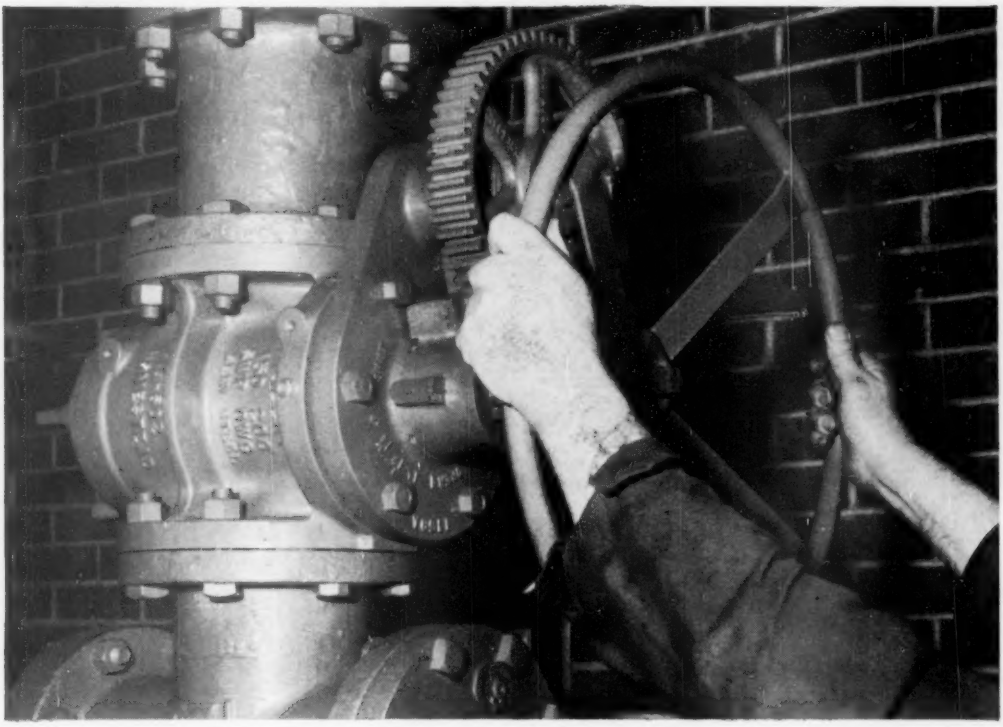
100% FLUID CONTROL AT YOUR FINGERTIPS

with Homestead Lubricated Plug Valves. When open, they provide full pipe-sized passage to fluids. Closed, their controlled high pressure lubricant



system, plus extremely close plug and body tolerance, guarantee a complete chemical seal—positive shut-off without contamination of line fluids. Instant response is sure, too, because piston-like movement of plug during each lubrication prevents sticking. They are low in first cost—low in upkeep. Write for complete details.

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HOMESTEAD VALVE MANUFACTURING COMPANY
P.O. Box 48, Coraopolis, Pennsylvania

48

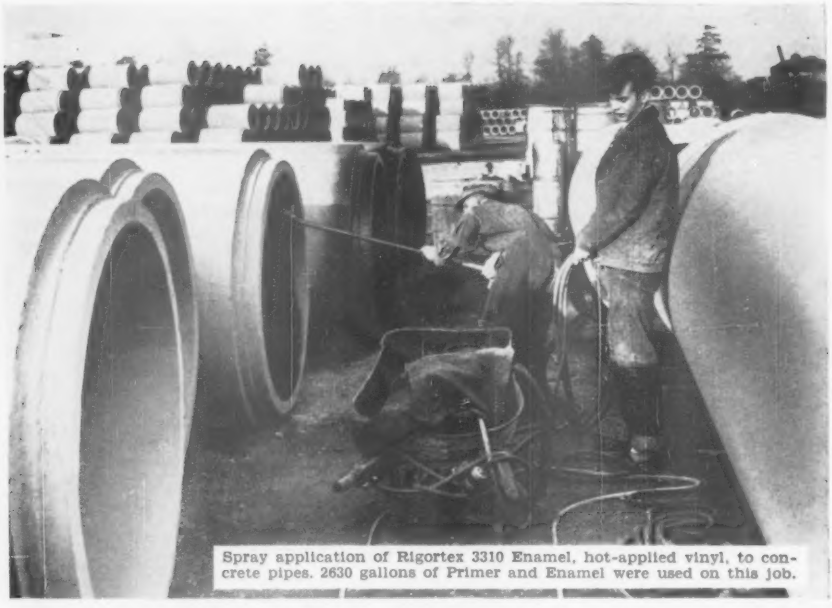
Gentlemen: Please send me Catalog 39-1 and prices on Homestead Lubricated Plug Valves

Name..... Title.....

Company.....

Address.....

City..... Zone..... State.....



Spray application of Rigortex 3310 Enamel, hot-applied vinyl, to concrete pipes. 2630 gallons of Primer and Enamel were used on this job.

Inertol® Hot-Vinyl Coating Protects South River Interceptor Sewer Pipe

As part of New Jersey's Raritan River clean-up project, the Middlesex County Sewerage Authority was to lay 25,370 lineal feet of concrete interceptor sewer pipe. In addition to domestic sewage, the pipe was to carry harsh acid and alkaline industrial wastes.

Too big a job for bituminous coatings, consulting engineers Bogert and Childs specified the Inertol Rigortex® 3310 Hot-Vinyl System. It has outstanding resistance to chemical conditions–including hydrocarbon wastes. It bonds exceptionally well and provides high-velocity flow. It is economical–gives almost 5 times as great mil thickness per coat as cold-applied vinyls, plus 30% savings in labor, and 10% in material.

First, one coat of Rigortex 3310 Primer was applied by spray (dry film thickness of 1.5 mils). Then one coat of Rigortex 3310 Enamel was applied by hot-spray (4.5 mils), producing the specified total dry film thickness of 6.0 mils.

A paint best suited to *your* problem can be selected from Inertol Company's complete line of protective-decorative coatings. Buy Inertol paints direct from manufacturer. Shipment within 3 days from our plant or warehouse stocks in your area. Write for Rigortex 3310 specifications on your letterhead, giving your title. For full specifications on Inertol coatings for sewage plants and water works, ask for free booklet SI-482-27H.

A complete line of quality coatings for water, sewage and industrial wastes plants and swimming pools.

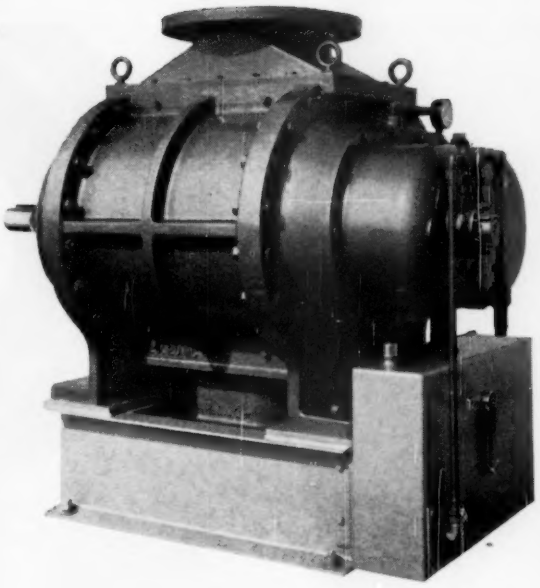
Inertol®

INERTOL CO., INC.

482 Frelinghuysen Ave., Newark 12, N. J. • 27-H South Park, San Francisco 7, Calif.

NEW SUTORBILT SERIES 3200 BLOWERS AND GAS PUMPS

with one-piece shafts for greater efficiency at increased horsepower and pressure ratings



New Series 3200 Sutorbilt lobe-type rotary positive blowers and gas pumps feature *one-piece* shafts. Forged from a single billet of 4140 alloy steel, they are slip fitted through—and bolted to—the impellers at the gear end.

Why a One-Piece Shaft? These heavy duty, high performance units must operate safely from 800 to 20,000 cfm at pressures from 2 to 10 psi. Incorporating this advanced shaft design in all 42 sizes eliminates using the drive impeller to transmit power . . . and greatly reduces the torsional deflection of the shaft between the timing gears and the impellers. And this one-piece shaft also eliminates adding outboard bearings for V-belt drive with normal working loads.

Other Outstanding Features include oversize heavy duty, anti-friction roller bearings with lip-type oil seals, machined sub-bases, alloy steel precision machined helical timing gears piloted to the shafts for concentricity, close grain cast iron impellers and a reversible oil pump with an oversize sump that eliminates the need for an oil cooler at ambient temperatures below 125 °F. In gas and high vacuum pumps, mechanical seals prevent leakage or gas contamination.

For more information and detailed specifications on these powerful, peak-performance units, write today, Department E.

Representatives in principal cities. Consult your classified telephone directory.

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CORPORATION, 2966 EAST VICTORIA ST. • COMPTON, CALIF.
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FULLER COMPANY GENERAL AMERICAN

"here's what out of sight out of mind" does to a water main

"Out of sight—out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated *eight inch* main whose *inside diameter was reduced to an average of almost 4.5 inches.* Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the *low cost* of National water main cleaning.

Since there's never a charge or obligation to inspect your mains, *call National now!*

Call in National today!

NATIONAL WATER MAIN CLEANING COMPANY

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Specify
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for every job
Iowa's complete line of valves for treatment plants assures you of efficient operation, low maintenance cost, and replacement parts when needed in years to come.

IOWA CHECK VALVES—Swing gate type for use in either horizontal or vertical pipe lines. Bronze trimmed throughout. Stainless steel hinge pins. Leather or rubber faced gates, or solid bronze, as desired—aluminum gates available for air service.

IOWA MEDIUM AND LOW PRESSURE VALVES—either non-rising stem or outside screw and yoke types. Designed as carefully as those conforming to A.W.W.A. specifications but with lighter construction for lower pressures.

Write TODAY for descriptive literature

IOWA FLAP VALVES—all iron; can be furnished with bronze hinge bolts or fully bronze mounted—including bronze bolts, flap ring and seat ring—when required.

CLOW HYDROSTATIC RELIEF VALVES — commonly used in bottom of concrete tanks to prevent ground water from floating the tank. Close-grained cast iron body and lid; lead seat ring and lid ring. Cast iron grate in bottom prevents foreign matter from entering tank.

IOWA PLUG DRAIN VALVES—either rising or non-rising stem type. High strength cast iron bodies; bronze stem, operating nut, disc ring and seat ring; rustproof steel bolts and nuts. Handwheels, extension stems, plain or indicating floor stands if required.

IOWA SLUICE GATES—can be used in lines having both seating and unseating pressures. High strength cast iron, bronze mounted, with solid bronze adjustable wedges. Can be equipped with cylinder or motor unit for automatic operation.

IOWA SHEAR GATES—either all iron or iron, bronze mounted. Gate-seating wedges bolted on, permitting replacement without replacing frame.

For 50 years a reliable source for **precision engineered products**

IOWA VALVE COMPANY

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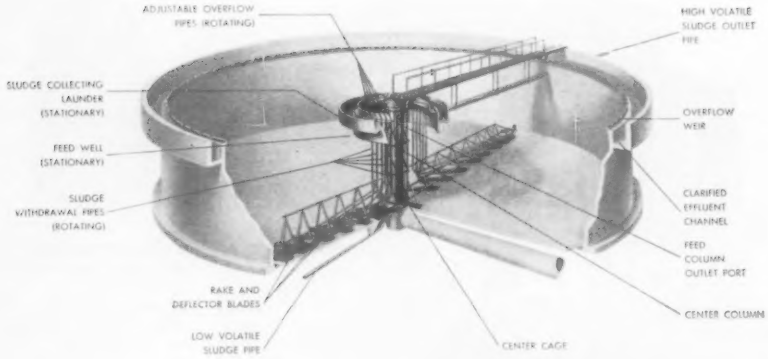
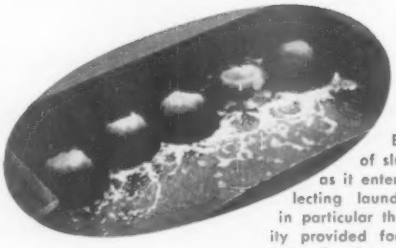


3-WAY CAPABILITY of the RSR Clarifier to make high-volatile sludge, low-volatile sludge and clarified effluent separation is illustrated in the cutaway drawing.



VISUAL EVIDENCE of sludge flow as it enters the collecting launder. Note in particular the flexibility provided for varying sludge flow from each individual uptake pipe.

NOW... *Rapid, continuous sludge removal with the new* **DORR RSR CLARIFIER**

For rapid removal of fresh sludge on a continuous basis, the Dorr® RSR Clarifier affords visual evidence of quality and quantity of sludge removed from secondary clarifiers. This is accomplished by removal of sludge from the entire floor area by rotating uptake pipes. Simple adjustment provides for controlled rate of sludge removal from each individual pipe.

In operation, a combination of rake and deflector blades channel the fresh sludge to an area under the withdrawal pipes where the sludge is lifted by hydraulic head to the collecting launder. Sludge flows from the launder to a sump for recycling or wasting following conventional practice. The sweeping action of the rake blades also provides for removal of grit and other inorganic material *without* dewatering the tank.

For information on the RSR Clarifier and on the complete line of Dorr-Oliver equipment and methods for sewage treatment, write Dorr-Oliver Incorporated, Stamford, Conn.

DORR-OLIVER

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

Sewage Works

THE EFFECTS OF ABS ON ANAEROBIC SLUDGE DIGESTION

By John W. Hernandez and Don E. Bloodgood

Associate Engineer, Environmental Sanitation Services, New Mexico Department of Public Health, Santa Fe, N. Mex.; and Professor of Sanitary Engineering, Purdue University, Lafayette, Ind.

Much experimental work has been carried out during the past ten years to determine the effect of synthetic detergents on sewage treatment processes and on stream purification. The increased use of detergents for industrial and household purposes has made them a common constituent of domestic sewage. Treatment plant operators have associated many of the new problems in sewage treatment to this increased use of synthetic detergents.

Three basic types of synthetic detergents are manufactured; anionic, cationic, and nonionic. Anionic detergents are of principal interest, as 80 to 90 per cent of all synthetic detergents produced are of this type (1)(2). Alkyl benzene sulfonates (ABS) are reported to make up approximately 50 per cent of the anionic detergents sold (3).

The concentration of syndets in domestic sewage appears to be from 1 to 10 mg/l, although some reports of higher concentrations are found.

The amount of synthetic detergents removed with primary sludge appears to be in doubt. Reports of the quantity of syndets removed from raw sewage vary from 30 to 50 per cent (4), 10 to 25 per cent (5), 33 per cent (6), and 2 to 4 per cent (7). McGauhey and Klein (7), in reporting concentrations of 2 to 4 per cent, state that "reports of 30 per cent or greater removal of ABS by sedimentation are based on methods of analysis which are shown to be grossly inaccurate."

Of particular interest are studies concerned with the effect of syndets on anaerobic sludge digestion. Principal references in this area include Rudolfs *et al.* (8), Rudolfs (9), Manganelli (10), Degens *et al.* (11), Roberts and Lawson (12), and Bloodgood and Johnson (13). There also appears to be some disagreement among these writers. Rudolfs (9), in a discussion of an article by Flett and Hoyt (4), states that "Carefully controlled experiments have shown that 0.2-per cent anionic detergents on a dry solids basis present during digestion, has no effect; that with 1 per cent there is some retardation, but no material effect; but when the percentage of detergents becomes higher, the effects become serious." Manganelli (10) carried out laboratory studies by adding 10, 25, 50, and 100 mg/l of three package synthetic detergents (one anionic, one cationic, one nonionic) to a 1:1 ripe sludge-fresh solids mixture, and allowing the mixture to digest for 31 days at 20°C. No inhibition or retardation of the digestion process resulted at lower levels while a slight retardation in gas production occurred at the highest level (100 mg/l). Degens *et al.* (11) found that for syndet concentra-

tions of less than 500 mg/l, surface active ingredients, no noticeable reduction in methane production resulted in laboratory digestion units, while concentrations of 1,000 to 5,000 mg/l inhibited methane gas production.

Raybould and Thompson (6) report that the addition of 600 mg/l surface active material (no additives) to an operating digester initially inhibited gas production. Gas production recovered in about one month and leveled off at 85 to 95 per cent of the gas production rate observed in a control digester. When a syndet containing additives or builder materials was added to a digestion unit, a much longer lag in gas production resulted. Raybould and Thompson (6) indicate that the builder material may be more troublesome than the detergents themselves. These investigators report that secondary alkyl sulfates were completely destroyed in digestion but that only 15 to 20 per cent of the alkyl aryl sulfonates were destroyed in the digestion process.

Roberts and Lawson (12) report syndet concentrations of 1.15 per cent of the dry matter in digested sludge at the Litchworth sewage works. These two investigators conducted laboratory experiments to determine the fate of synthetic detergents in sludge digestion. A mixture of three parts raw sludge and one part digested was incubated for 31 days. The concentration of syndets at the beginning of the digestion period was 1.25 per cent on a dry matter basis. After the 31-day digestion period, the syndet concentration had increased to 1.35 per cent, while the volatile content of the mixture was reduced from 69 to 52 per cent. Roberts and Lawson (12) conclude that the syndet associated with sludge going into a digester is broken down to a very limited extent.

Bloodgood and Johnson (13) conducted laboratory studies on the effect of ABS and vegetable oil on anaerobic digestion. The ABS concentration in a laboratory digester was increased from 58 to 95 mg/l with a single addition of 37 mg/l ABS and then daily additions of 3.7 mg/l were made in order to maintain a net increase of 37 mg/l with a daily removal of 100 ml. They concluded that the presence of ABS in a concentration of 95 mg/l will result in a serious decrease in gas production, a decrease in the destruction of volatile matter, and a decrease in pH.

Results of some of these studies are expressed as "packaged synthetic detergents" and others are in terms of "surface active material." The portion of surface active material in a packaged product varies from 20 to 35 per cent (14). This factor should be kept in mind in evaluating reported studies.

Laboratory Studies

The results of these investigations appear to be somewhat contradictory; therefore, a laboratory study was undertaken to investigate the effects on anaerobic sewage sludge digestion of the addition of an anionic synthetic detergent to a laboratory digestion unit.

The experimental apparatus consisted of two typical laboratory digestion units. Each unit consisted of a four-liter aspirator bottle with openings at the top, and on one side at the bottom. The top opening was fitted with a two-hole rubber stopper; one for feeding, and the second for gas removal. The bottom hole was fitted with a one-hole stopper and glass tube to permit withdrawal of the material.

Three liters of a digesting sewage sludge (five-per cent solids) were placed in each aspirator bottle, and the three-liter level marked. Gas was collected in two sets of one-liter cylinders inverted in two-liter cylinders. Tap water was used as a liquid seal between the one-liter and two-liter cylinders. The one-liter cylinders floated free when buoyed up by digester gas.

Both digestion units were housed in a common incubator at 35°C. The gas collection cylinders were located outside the incubator, and were therefore subject to changes in room temperature.

Previous investigations (13) have shown that laboratory scale digestion studies carried out under carefully controlled conditions are practical, and that two or more laboratory digestion units operated in the same manner may be expected to produce approximately equal volumes of gas. To accomplish the objectives of this study, two laboratory digestion units were set up and operated for 37 days, with equal volumes of digested sludge removed daily, equal volumes of raw feed sludge added daily, and equal daily mixing given each unit.

After the two digestion units had been operated in a similar fashion for 37 days, periodic additions of an anionic synthetic detergent were made to the test digestion unit, and the effects of the increased concentration observed by various digestion indexes.

Summary of Initial Phase

Each day during the first 37-day period, both units were serviced in a similar manner. Daily servicing consisted of (*a*) mixing by vigorous shaking, (*b*) reading gas volume and releasing gas pressure, (*c*) removing a small volume of digesting sludge mixture (50 to 100 ml), (*d*) replacing this volume with fresh raw sewage sludge, and (*e*) mixing and incubating for 24 hr. The organic loading, added daily to the two units, was increased in four increments to a daily loading of 3.5 g/day of volatile solids. Once reached, this organic loading was maintained throughout the study. Minor variations in daily gas production occurred during the initial "buildup" phase. However, the difference in cumulative gas production at the end of the period was 190 cc of gas, or approximately 0.33-per cent difference in the two units. The total gas production during this period was 56,335 cc for the test unit, and 56,145 cc for the control unit. Similarity of operation of the two units was also observed by the determination of volatile acids, pH, and total and volatile solids for each unit. From experimental data, the two units were operating in a like manner.

Addition of ABS to a Laboratory Unit

Operation

The second phase of the investigation was conducted as a study of the effects of the addition of ABS to one of these laboratory units on the continuous anaerobic sludge digestion process being carried out. Periodically throughout this second phase, the concentration of anionic synthetic detergets in the test unit was increased by the addition of a solution of ABS.

In order to correlate data obtained with that from other studies on synthetic detergents, a standard anionic detergent was used. Such a standard anionic detergent was formulated by the Association of American Soap and Glycerine Producers as a reference material for use in laboratory investigations.

The two digestion apparatus were serviced and operated in the same fashion throughout this part of the study, as in the initial phase, with the exception of the addition of ABS to the test unit. A standard stock solution of ABS was prepared, which contained 1,000 mg/l of ABS. The level of the concentration of ABS in the test unit was increased six times during this second phase; the increase being 10 mg/l on each occasion by the addition of 30 ml of the standard stock solution to 3 liters of the digesting sludge mixture in the test unit. The standard stock solution was "added" directly to the test unit by means of a pipette. The term "added" refers to the ABS not naturally present in the sewage

sludge, and that which was "added" in the form of ABS standard stock solution.

Small additions of ABS to match approximately daily withdrawals of "added" ABS were made to the test unit. The daily addition of these small quantities of ABS was based on two important assumptions. The first assumption was that by mixing before daily withdrawals, a homogenous mixture was removed, and that the amount of "added" ABS withdrawn daily was proportional to the concentration of "added" ABS in the test unit. The second assumption was that no decomposition of the "added" ABS takes place with the digestion of organic material.

As noted above, the first addition of ABS to the test unit was 30 mg or 10 mg/l. During the 10 days which followed the first addition, daily servicing was performed on each unit. No daily additions of ABS were made during this first 10-day period.

Routine observations of pH, total and volatile solids, volatile acids, and gas production were made for each unit. None of these parameters of sludge digestion gave any indication of a change in the digestion process in either laboratory unit.

Results

At the end of 10 days, the concentration of "added" ABS was 7.8 mg/l. Thirty milligrams of ABS were then added to the test unit, and a second 10-day observation period followed. Daily servicing was carried out during this period with small daily additions of ABS to the test unit. No adverse effect on the digestion process was observed during this period. The concentration of "added" ABS was then increased, and a third 10-day period followed. Once again, this increase in "added" ABS caused no marked detrimental effects. A pictorial presentation of the gas production for the first three increases in "added" ABS may be found in Figure 1.

The cumulative gas production for this 30-day period was 63,320 cc for the control unit, and 62,595 cc for the test unit, or approximately a 1-per cent variation in the two units. Likewise,

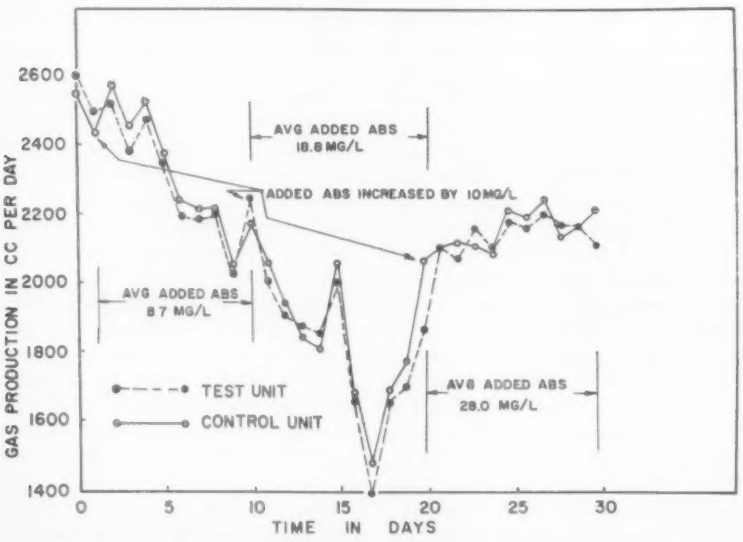


FIGURE 1.—Daily gas production for first three increases in added ABS.

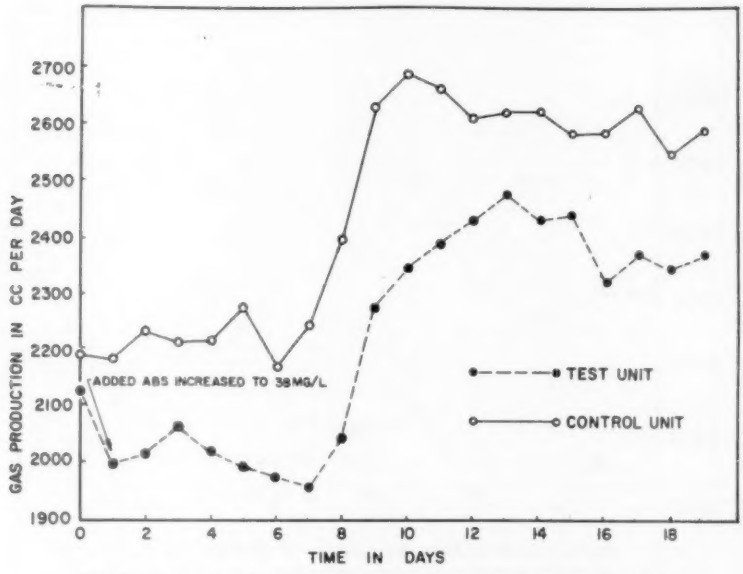


FIGURE 2.—Daily gas production after fourth increase in ABS.

other parameters measured showed little if any variation in operation of the digestion units. The calculated concentration of "added" ABS at the end of this 30-day period was 28.3 mg/l.

The concentration of "added" ABS was again increased by 10 mg/l for the fourth time. The first significant difference in daily gas production in the two units occurred after this addition. The "added" ABS concentration had been increased to 38 mg/l. As may be seen from Figure 2, a sharp decrease in gas production in the test unit resulted. In order to evaluate this decrease in gas production, a 19-day observation period followed. Usual daily servicing and small daily additions of ABS to the test unit were carried out during this time. The average daily gas production for the control unit during the 19-day period was 2,440 cc, as compared to 2,235 cc for the test unit. The difference in daily gas production between the two units leveled off at from 150 to 200 cc/day, or approximately a 7-per cent reduction in the daily gas production. Small daily additions of ABS to replace "added" ABS removed by daily withdrawals of digested sludge did not appear to have any detrimental effect on daily gas production, as the difference in daily gas production between the two units became relatively constant within 12 days.

After 19 days the ABS concentration was increased, this time to 49 mg/l "added" ABS. The difference in daily gas production in the two units became greater with this addition of ABS. The average daily gas production, in the 10 days which followed, was 2,600 cc/day for the control unit, and 2,321 cc/day for the test unit. The daily difference again leveled off at 250 to 300 cc difference per day, indicating no serious inhibition in the digestion process (Figure 3). Volatile acids concentrations and pH values of the two units were similar throughout this 10-day period.

As a 10-per cent reduction in gas production appeared to be the only difference in operation of the two units,

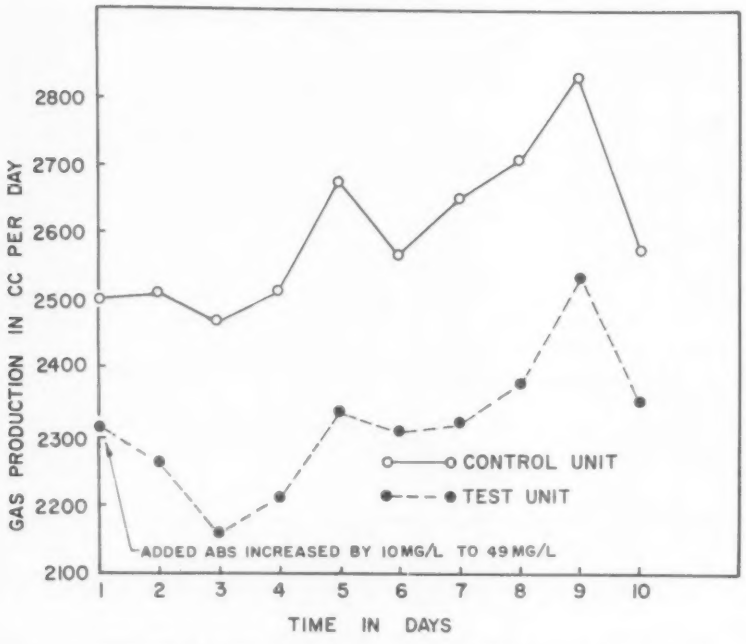


FIGURE 3.—Daily gas production after fifth increase in ABS.

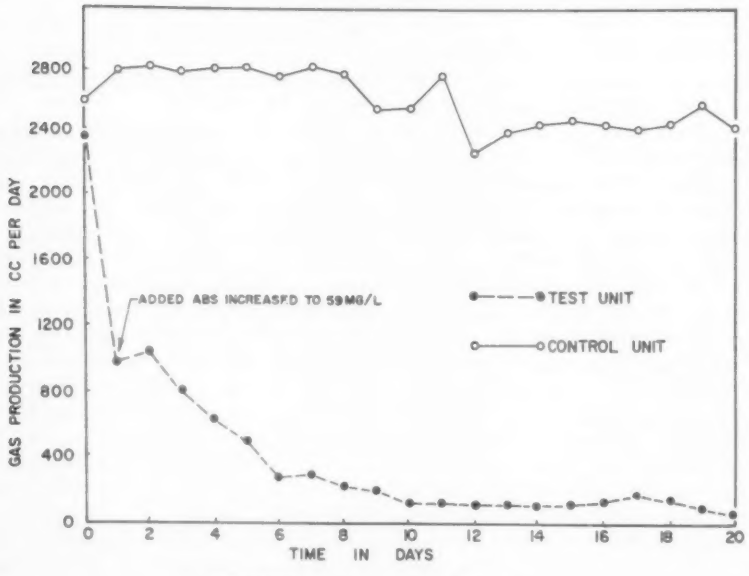


FIGURE 4.—Daily gas production.

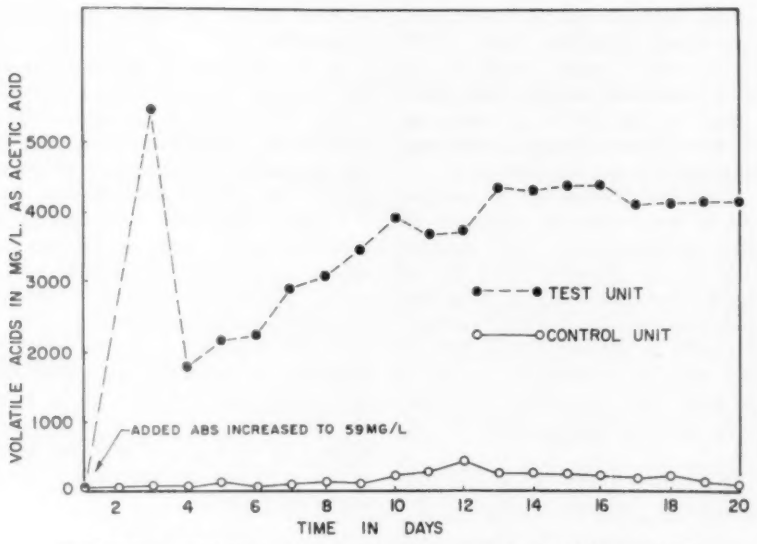


FIGURE 5.—Volatile acids concentration after final addtion of ABS.

the concentration of "added" ABS was again increased by 10 mg/l to 59 mg/l "added" ABS. A serious disruption in the digestion process in the test unit resulted as shown by: (*a*) gas production decreased by 1,370 cc the first day after the addition of ABS, and continued to decrease to virtually no gas production (Figure 4), (*b*) the volatile acids concentration increased from 120 to 5,560 mg/l as acetic acid after the final addition of ABS (Figure 5), (*c*) the pH decreased from 7.2 to 6.9 the first day after the final addition of ABS, and continued to decline through the next 20 days, (*d*) the volatile solids in the test unit increased from 65.9 (average value for previous 10 days) to 70.0 per cent (average value for next 20 days). Other physical phenomena which are sometimes characteristic of "poor" digestion and were observed during the final period of operation of the test unit were: (*a*) sour, disagreeable odor; (*b*) color change from dark green-black to gray; (*c*) solid material forming whitish foam or scum; (*d*) cloudy, supernatant layer with some floating solids; and (*e*) solid material lifted as a body to the surface of the liquid in the digestion unit.

Subsequent analysis of the contents of the test unit for ABS showed the concentration to be 107 mg/l ABS. Analysis of sewage sludge or even sewage by the conventional methyl green method (2) is not possible. Adsorption of the ABS to the surfaces of suspended solids does not permit a true analysis. A modification of the method suggested by Roberts and Lawson (12) was used in this analysis.

The concentration of ABS per gram of total solids in the test unit was found to be 3.33 mg/g. Samples of digested sludge from an operating field digestion tank were also analyzed for ABS. The average concentration of ABS in this functioning field unit was 272 mg/l, but the concentration of ABS per gram of total solids was only 2.0 mg/g.

Conclusions

Based on the laboratory studies carried out, the following may be concluded:

1. Two conventional laboratory anaerobic sludge digestion units, when operated under equal conditions of daily withdrawals, mixing, and feeding, may be expected to produce approximately equal volumes of gas, and to function in a similar manner.

2. A gradual increase in the concentration of alkyl benzene sulfonate by periodic additions of an ABS solution to a laboratory digestion unit has no apparent effect on the digestion process until the concentration of the "added" ABS (ABS in excess of that present in the raw feed sludge) reaches a higher level, when a noticeable decrease in daily gas production may be expected.

3. Subsequent increase in the concentration of "added" ABS will result in larger decreases in daily gas production.

4. An increase in the concentration of "added" ABS will be reached which will result in a serious disruption of the digestion process, such that the anaerobic decomposition of organic solids and gas production will cease.

5. The important relationship appears to be the ratio of ABS to total solids, or possibly to particle surface area. No work was done to evaluate the surface area consideration, but the fact that digestion units are operating satisfactorily with 272 mg/l ABS indicates that concentration alone is not the dominant factor. An ABS concentration of 3.3 mg/g of total solids will result in a serious disruption of the digestion process.

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DENSITY OF ENTEROVIRUSES IN SEWAGE

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The plaque-forming activity of viruses in tissue culture (1) lends itself to the enumeration of several kinds of enteroviruses in sewage. Heretofore, demonstrations of enteroviruses in human wastes have been qualitative. This report describes a quantitative method for their detection in sewage and its use for the estimation of enterovirus densities.

Methods

Samples of raw and treated sewage were collected from several treatment plants as the liquid expressed from cheesecloth swabs exposed to flowing sewage for from 24 to 48 hr. This sampling technique has been valuable for the detection of bacterial (2) and virus pathogens (3) that may occur intermittently in sewage. It was observed that these swab expressions contained enteroviruses and bacteria from two to four times more often than comparable catch samples (3)(4). Several catch samples were also obtained. The volume of swab expression was approximately 0.1 l; that of catch samples, either 0.4 or 4 l. All samples were concentrated on Dowex 1 resin (3), eluted, treated with antibiotics and diethyl ether to reduce bacterial and fungal contaminants, and stored in a dry-ice chest. The eluates were added in 0.5-ml amounts to monolayers of monkey kidney epithelium tissue that had been grown several days in 4-oz bottles. The inoculated tissue cultures were rinsed with 199H solution one-half hour later and overlaid with a nutrient agar containing neutral red (5). They were incubated at 33°C and examined daily for plaque formation until the tissue degenerated. Virus presence was confirmed by propagating a salt diffusate from the plaques in tube cultures of monkey kidney epithelium tissue. Viruses were identified serologically by neutralization tests. A few eluates were also tested for plaque formation in bottle cultures of FL amnion cells (6).

Virus densities were estimated from the number of plaques formed, corrected for the total volume of sample. The results are expressed as number of plaque-forming units (PFU) in 100 ml of swab expression. A sample calculation follows:

Given:

Number plaques formed	=	4
Volume inoculum (ml)	=	0.5
Volume concentrated sample (ml)	=	10
Volume swab expression (ml)	=	100

Then:

$$4 \times \frac{10}{0.5} = 80 \text{ PFU/10 ml concentrated sample}$$

Or:

80 PFU/100 ml swab expression.

To relate the values found in the swab expressions to those expected in catch samples, on which other parameters of sewage are usually based, the extent of concentration by the swab sampling technique was determined. A comparison was made of the densities of enteroviruses and coliform bacteria and of values for nitrogen, chloride, and chemical oxi-

TABLE I.—Frequency Distribution of Values for the Density of Enteroviruses in Swab Expressions of Sewage

Year	PFU/100 ml											Total No. of Samples
	20	40	60	80	100	120	140	160	180	200	400	
1956	2	4	—	1	—	—	—	—	—	—	—	7
1957	11	8	4	2	5	1	1	3	1	2	1	39
1958	11	7	7	2	1	—	—	—	—	—	—	28
1959	18	5	4	1	—	2	—	—	—	2	—	32

dation demand in swab expressions and comparable catch samples. Parallel samples were obtained by exposing swabs to raw sewage for periods of from 1 to 4 hr and by compositing catch samples according to flow during the same periods. Fifty-milliliter volumes of the swab pressings or 100 ml of the composite samples were concentrated as described, for the estimation of enteroviruses as PFU/100 ml sample and as per cent of tube cultures of monkey kidney tissue showing cellular degeneration. Coliform bacteria were estimated as most probable number (MPN) per 100 ml of sewage by the confirmed test (7). Chemical oxidation demand (COD) was expressed as mg/l by the acid dichromate method (7); organic and ammonia nitrogen as mg/l by the total Kjeldahl method (8); and chlorides as mg/l by the Mohr method (7).

TABLE II.—Kinds and Typical Densities of Enteroviruses in Swab Expressions

Viruses* Isolated from Swab Expressions as Plaques	Density (PFU/100 ml)
B_5	20
B_4, E_{12}	100
B_4, E_7	60
B_4, B_5	400
P_2	160
P_1	100
P_1, B_5	40
B_4, E_8	40
P_3	20
B_2	20
P_1, P_3, B_5	80
P_3, E_9	40
E_1	20
E_6	20

* B = Coxsackie virus Group B; E = ECHO virus; and P = Poliovirus.

Results

Table I summarizes the densities of enteroviruses found in the swab expressions. Densities below 20 and above 400 PFU/100 ml were not demonstrated by this method. Most (90 per cent) of the samples in which PFU were found contained 100 PFU/100 ml or less, i.e., 1 or less/ml swab expression.

At least 14 kinds of viruses were isolated as PFU (Table II). They were usually isolated as single strains; isolations of two viruses from one plaque were rare. Fifteen per cent of the samples contained mixtures which were resolved by propagating virus from two or more plaques.

The values of all parameters of sewage measured were higher in the swab expressions than in the catch samples (Table III). Maximum concentration factors found were: coliform bacteria, 10 times; enteroviruses, 9 times; COD, 9 times; nitrogen, 3 times. The concentration factor for all parameters but the coliform bacteria increased in the swab expressions with increasing periods of exposure to sewage up to the third hour. The greatest changes with time in the swab expressions occurred in the COD values, which increased 10-fold in the 4-hr period. Nitrogen increased 3 times and enteroviruses, 5 times. Values in the composite samples did not reflect the increases.

In another comparison of these parameters and of chlorides in samples collected over a 48-hr period, maximum concentration factors were observed as

TABLE III.—Values of Parameters in Hourly Swab and Composite Samples of Influent Sewage

Hours of Sampling	COD (mg/l)		N (mg/l)		Coliform Bacteria (MPN/100 ml)		Viruses (PFU/100 ml)	
	Swab	Composite	Swab	Composite	Swab	Composite	Swab	Composite
1	562	512	57	63	2.4×10^9	1.5×10^8	30	20
2	2,640	671	108	58	2.4×10^9	4.6×10^8	20	20
3	5,540	590	175	48	4.6×10^9	4.3×10^7	90	10
4	4,760	630	132	49	2.4×10^9	2.4×10^8	160	20

follows: coliform bacteria, 100 times; nitrogen, 10 times; COD, 16 times; chlorides, 1.7 times; and enteroviruses, 4 times. The greatest increase in concentration factor in the swab expressions took place for coliform bacteria during the first 12 hr; for nitrogen and COD, in the first 18 hr; and for chlorides and viruses, in 42 hr. These changes were not reflected in the values from the composited samples.

When the maximum concentration factor of 9 is used to relate the density of enteroviruses in swab expressions to that expected in catch samples of sewage, densities of from < 2 to 44 PFU/100 ml sewage may be predicted. Densities within this range of values were found in the single 4-l catch sample tested and in a 4-hr composite sample.

The enterovirus densities were estimated in samples collected at different periods of the year, and part of the variation noted, from < 20 to 400 PFU/100 ml, may be attributed to the seasonal occurrence of enteroviruses. Figure 1 illustrates the fluctuation in enterovirus densities found in the swab expressions according to week of collection. Peak densities were usually found in August and early September, the period which coincides with that of maximum frequency of isolation. Minimal or undetectable amounts were encountered from December through

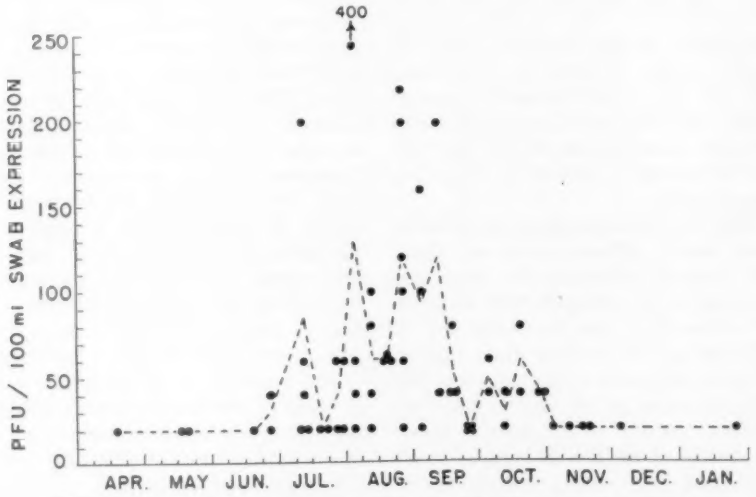

FIGURE 1.—Density of enteroviruses in PFU/100 ml swab expression according to months, 1956–1959.

TABLE IV.—Enterovirus Densities at Various Stages of Sewage Treatment (PFU/100 ml swab expression)*

Plant	Raw	Effluent					
		Primary Treatment	Secondary Treatment				
			Trickling Filters	Secondary Settling and Chlorination	Aeration	Secondary Settling	Returned Sludge
a	54	45	—	—	—	—	—
b	124	90	68	32	—	—	—
c	160	—	<20	<20	—	—	—
d	100	100	—	—	<20	<20	28
e	100	<20	—	—	—	—	—
f	80	<20	—	—	—	—	—

* Average of from 1 to 15 samples per value.

May. The distribution of kinds of enteroviruses during the year has been discussed previously (9).

The densities also varied with the kind of sewage sampled (Table IV). Swab expressions from raw sewage gave higher enterovirus densities than those from treated sewage, as might be expected. The density in effluents was similar to that in raw sewage at three primary treatment plants and was several times less in two other plants. The density in effluents of trickling filters was from 2 to 8 times less than in raw sewage and was still less in effluents that were chlorinated. In samples from sewage aerated with activated sludge it was no more than one-fifth that from untreated sewage. These reductions after treatment verify previous observations of the effectiveness of sewage treatment in removing enteroviruses.

Replicate estimates made on different days, using different lots of tissue and involving additional freezings and thawings of the samples, had an average deviation from the mean of 30 PFU/100 ml, no greater than that in replicate estimates made the same day using the same lot of tissue. The estimates of density in FL amnion tissue cultures were too few to compare with those made in monkey kidney tissue. It was noted, however, that if densities in this series of samples were high when measured by one technique, they were usually high by the other technique. This measure of variation is complicated, of course, by the selective action of the two kinds of tissue cultures for viruses.

Discussion

The density of enteroviruses in sewage is low in comparison with that of coliform bacteria, the indicator of sewage pollution. This suggests that even at the height of the enterovirus season the population is discharging enteroviruses in small amounts. The low densities are probably not the result of inactivation of viruses en route to the plant since detention by primary treatment does not invariably affect the density. The density of coliphage (10) is higher than that of the enteroviruses encountered here, an expected difference, perhaps, since the host for the phage is abundant in sewage. The densities of *Salmonella* and other bacterial pathogens in sewage are reported by some to be higher than (11) (12) and by others to be the same as (13) (14) those found for the enteroviruses.

The presence of minimum densities of virus in the winter months indicates that there is a small constant reservoir of enterovirus infection in the population regardless of season.

The failure of the swab expressions to exhibit a concentration factor for

chlorides suggests that certain components of sewage, perhaps those in ionic form, are not "caught" by the swab.

This method does not measure the density of enteroviruses which do not form plaques readily in the tissue cultures cited.

Summary

The density of plaque-forming enteroviruses in sewage, estimated from the density of PFU in swab expressions, was from < 2 to 44 PFU/100 ml. Results of estimates using catch samples were in this range. Highest densities were found in August and early September and in samples of raw rather than treated sewage. The enteroviruses isolated as PFU were identified as strains of Coxsackie, ECHO, and polioviruses. The extent to which certain components of sewage were concentrated by the swab was demonstrated.

Acknowledgment

The compositing of catch samples and the performance of chemical tests were supervised by Mr. William W. Ullmann.

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HAVE YOU PAID YOUR 1961 DUES? SEE PAGE 1299

TEMPERATURE REQUIREMENTS FOR ODOR DESTRUCTION IN SLUDGE INCINERATION

By Clair N. Sawyer and Peter A. Kahn

Metcalf & Eddy, Boston, Mass.

Incineration of sludges from sewage and industrial waste treatment operations is becoming more and more common as land areas for lagooning or drying beds become more difficult and costly to obtain. Furthermore, municipal officials and regulatory agencies are becoming reluctant to sanction such land disposal because of the public health aspects related to initial storage and final disposal. The former is of much concern where raw or poorly digested sludges are spread in open areas, since insects and rodents can utilize the organic matter to feed and breed; and the latter is of concern because final disposal of sludge often becomes the responsibility of farmers, truck and landscape gardeners, and others who may not care to conform to accepted safe practices for the use of such materials.

Incineration of sludges usually eliminates the public health problems of sludge disposal but it does not necessarily insure complete elimination of nuisances. Fly ash and odor problems are rather common and are becoming more so as expanding populations encroach on sewage treatment plant sites. Although tall stacks are a frequent solution to the problem, there are many situations where geographical conditions and prevailing winds bring about complications. A notable example was at Pittsburgh where public clamor, aroused by obnoxious odors, forced a shutdown of the incinerators after 5½ months of operation.

Because of the unusual aspects of the problem at Pittsburgh where primary sludge was being concentrated by the anaerobic flotation method (1), and incinerated without the addition of chemicals, it was deemed necessary to determine whether sludges thickened by this method had unusual temperature requirements for odor destruction.

Method of Study

Sludges

Primary sludges of widely differing characteristics were obtained from six treatment plants in Massachusetts and Rhode Island as shown in Table I.

Three of the sludges were predominantly primary sludges and three contained waste activated sludge. All plants received industrial waste to some degree.

The primary sludges were conditioned in four ways for odor destruction studies:

1. Raw sludge, centrifuging,
2. Raw sludge, chemical conditioning and vacuum filtration,
3. Anaerobic flotation, no treatment, and
4. Anaerobic flotation, lime to pH-9.

The character of the sludges used in terms of volatile solids and volatile acids was as given in Table II.

Digested sludge was obtained from five of the plants. The sludges were elutriated, conditioned with ferric chloride, and vacuum filtered in preparation for testing.

Apparatus

The studies on required temperatures for odor destruction were con-

TABLE I.—Source and Nature of Primary Sludges

Source	Primary	Primary and Activated	Relative Amount Industrial Wastes
Boston, Nut Island	√	—	++
Bucklin Point	√	—	++++
Cranston	—	√	++
East Providence*	√	—	+
Leominster	—	√	++
Providence	—	√	++

* Contains trickling filter humus.

TABLE II.—Character of Primary Sludges Used

Source	Volatile Solids (per cent)	Volatile Acids (mg/l)	
		Raw	After Flotation
Boston, Nut Island	82.8	840	3,400
Bucklin Point	78.4	150	3,360
Cranston	78.2	820	3,900
East Providence	56.2	37	2,075
Leominster	83.9	120	9,400
Providence	72.2	150	4,010

ducted in a Lindberg combustion furnace. An extra long transparent combustion tube was used so that the samples contained in "boats" could be heated in the tubes outside the furnace and only the vapors from drying of the sludge passed through the combustion furnace. In this way, conditions comparable to actual incineration practice were simulated. Two "boats" were normally inserted in the drying section of the tube. One contained wet sludge and the other dried sludge. The latter was included to yield some vapors from charring reactions that are known to occur in sludge drying. Air was supplied to the system by means of a small air pump and the flow was controlled by measurement with a rotameter to allow a 0.7-sec exposure in the combustion furnace. The gases escaping from the furnace were collected in polyethylene bags for odor evaluation. A diagram of the experimental apparatus is shown in Figure 1.

The temperature indicator on the furnace was calibrated by inserting a thermocouple inside the combustion tube under actual operating conditions. Tests on each sludge were initiated at the highest temperature, usually 1,450°F, and then decreased at 50°F intervals, in order to avoid carryover of odorous materials from one test to another. New portions of sludge were used for each temperature studied and the discharge end of the combustion tube was cleaned before starting a new series of studies with a different sludge.

Odor Panel

The original plan was to use about five women and five men as a test panel. The use of women had to be abandoned as they found odors on

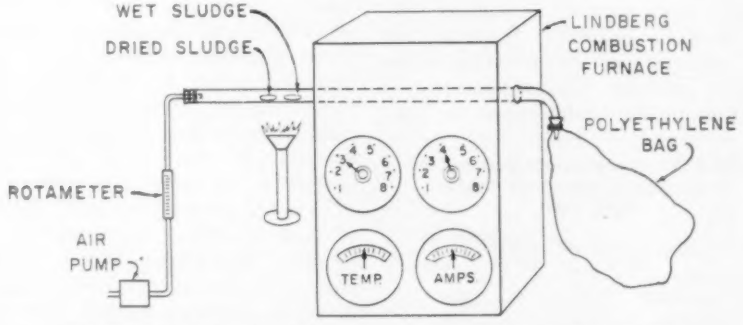

FIGURE 1.—Experimental apparatus for odor destruction studies.

TABLE III.—Temperatures Required for Odor Destruction (°F)*

Source of Sludge	Raw Sludge		Floated Sludge		Digested†
	Centrifuged	Chemically Conditioned	No Treatment	Lime Conditioned	
Boston, Nut Island	1,350	1,400	1,400	1,350	1,350
Bucklin Point	1,250	1,250	1,350	1,250	1,300
Cranston	1,350	1,300	1,300	1,300	1,300
East Providence	1,350	1,300	1,300	1,250	1,300
Leominster	1,300	1,350	1,300	1,300	1,350
Providence	1,300	1,300	1,300	1,250	—

* Actually threshold temperature or temperature at which slight odor was apparent to some people.

† Conditioned with $FeCl_3$.

occasion so repugnant that they refused to collaborate. Many of the men, particularly heavy smokers, had extremely insensitive and unreliable noses. After much trial and error, a panel of five men was selected. Each man made an independent evaluation and the results were recorded as P (pungent) or F (foul or nauseous), and the degree of odor expressed as: 0—none, 1—very slight, 2—slight, 3—distinct, 4—decided, and 5—extreme.

The recorded data were analyzed by one person to obtain critical temperatures as reported in this paper.

Results

A total of 29 sludge samples were subjected to test involving 174 odor evaluations by each of five people. The results of the study are summarized in Table III.

Because of the unusual amounts of volatile acids present in sludges concentrated by anaerobic flotation and the practice of incinerating such sludges without pH adjustment, a study was made to determine the temperatures required for destruction of the low molecular weight fatty acids commonly present in sewage sludge. The results are given in Table IV.

TABLE IV.—Temperatures Required for Destruction of Odors from Volatile Fatty Acids

Acid	Temperature (°F)
Acetic	1,370
Propionic	1,370
Butyric	1,425
Caproic	1,425

Discussion

It has generally been regarded by designers of incinerator equipment that maintenance of a temperature of 1,250°F in the deodorization chamber is adequate for destruction of odors from sewage sludges. Turk (2) has indicated that temperatures as high as 1,500°F are required for some materials. The data obtained during the course of the study reported indicates that a reasonably safe temperature is 1,350°F for most sludges and that 1,400°F would be required in some instances.

The economy of sludge incineration is seriously affected by the temperatures required for deodorization since heat losses to the stack vary accordingly. Efforts to maintain adequate temperatures in the deodorizing chamber often result in excessive combustion chamber temperatures that are conducive to slag formation. As a consequence, there is a tendency to operate at the lowest temperature possible in the deodorizing zone. Because of fluctuations in sludge quality, particularly with respect to moisture content, an appreciable variation usually occurs in the temperature maintained in the deodorizing zone. The signifi-

cance of these variations in relation to the type of sludge burned is shown in Figure 2. Assuming that the critical level for odor destruction is 1,350°F, a decrease in temperature to 1,300°F could result in a significant odor problem, depending on the type of sludge. A further decrease to 1,200°F or below could be extremely serious regardless of the type of sludge being burned, particularly when atmospheric conditions are unfavorable.

Conclusions

The temperature required for odor destruction varies somewhat with the character of the sludge processed and the method of concentration or conditioning. Sludges concentrated by anaerobic flotation did not have unusual temperature requirements. The vapors from only a few sludges were adequately deodorized at 1,250°F. Most required a temperature of 1,300

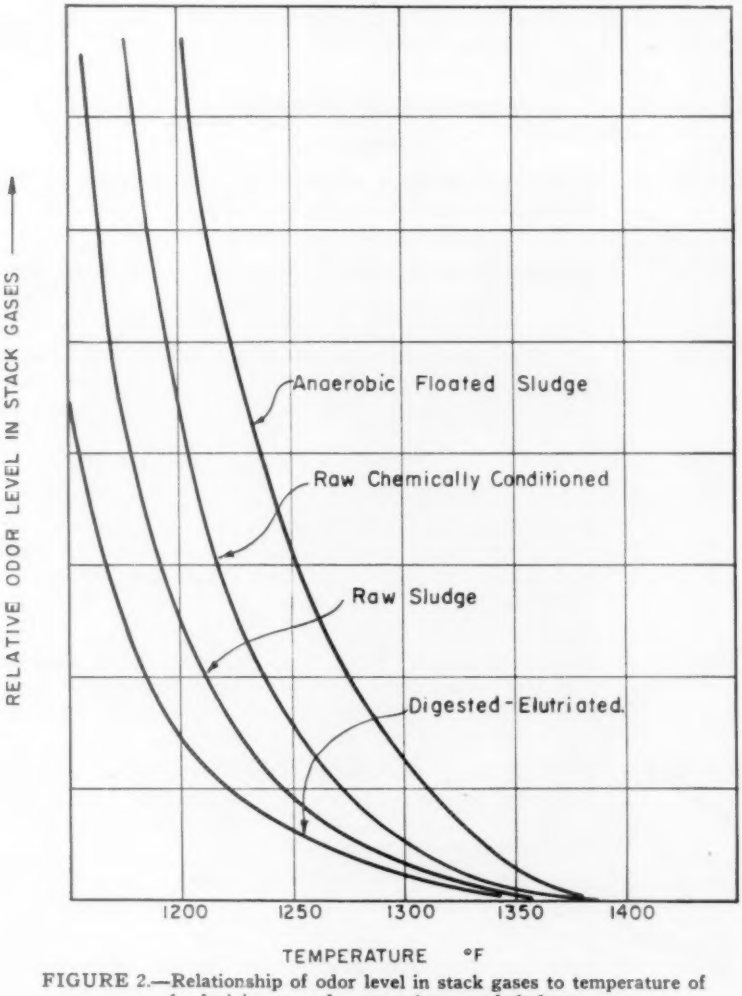

FIGURE 2.—Relationship of odor level in stack gases to temperature of deodorizing zone for several types of sludges.

or 1,350°F and a few required 1,400°F.

The intensity of odors was appreciable at 50°F below the threshold level and severe at 100°F below.

Temperatures required for destruction of odors from volatile fatty acids varied from 1,370 to 1,425°F.

Odor-free incinerator operation requires that strict attention be given to control of temperatures in the deodorizing zone and that a factor of safety be employed commensurate with atmospheric conditions and other local factors.

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MEETINGS OF INTEREST

1960

Dec. 12–14	**National Conference on Problems and Progress in Water Pollution Control,** Sheraton-Park Hotel, Washington, D. C. U. S. Public Health Service, Washington, D. C.
Dec. 15–16	**National Technical Task Committee on Industrial Wastes,** Sheraton-Park Hotel, Washington, D. C. L. F. Warrick, Public Health Service, Washington 25, D. C.
Dec. 26–31	**American Association for the Advancement of Science,** New York, N. Y. American Assn. for the Advancement of Science, 1515 Massachusetts Ave., N. W., Washington, D. C.

1961

Jan. 5–Mar. 23	**Theory and Operation of Sewage and Waste Water Treatment Processes,** Part 1 of 2-part seminar held at Newark College of Engineering, Newark, N. J. Co-sponsored by New Jersey State Dept. of Health and New Jersey Water Pollution Control Association. C. H. Stephans, Newark College of Engineering, 323 High St., Newark 2, N. J.
Jan. 23–27	**Rocky Mountain Water and Sewage Plant Operators' School.** University Extension Center, 1100 14th St., Denver, Colo. Professor Walter A. Weers, School of Civil Engineering, University of Colorado, Boulder, Colo.
Jan. 31–Feb. 1	**Third Sanitary Engineering Conference,** Urbana, Ill. Professor Ben B. Ewing, Dept. of Civil Engineering, University of Illinois, Urbana, Ill.; or C. W. Klassen, Illinois Dept. of Public Health, Springfield, Ill.
Feb. 19–23	**American Society of Civil Engineers,** Hotel Shamrock, Houston, Tex. W. H. Wisely, ASCE, 33 West 39th St., New York 18.
Mar. 21–30	**American Chemical Society,** St. Louis, Mo. American Chemical Society, 1155 16th St., N. W., Washington 6, D. C.

CONSTANT TEMPERATURE CONTROL UNIT

By J. A. Castelli, E. P. Pendery, and R. C. Palange

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Many sewage treatment plants and laboratories find it necessary to carry out occasional examinations for BOD, but the sample load is not large enough to justify purchase of a constant temperature incubator.

This paper describes a control unit for converting an ordinary home-type refrigerator to a constant temperature unit on an intermittent basis, as needed for incubation. The controls are designed to maintain a temperature within ± 2°F between 60 and 100°F on a small home-type refrigerator that does not exceed a 2.5-amp load. Between such uses, the refrigerator may be used for its normal purposes.

Materials

Table I shows the necessary materials for the unit.

FIGURE 1.—Assembled constant temperature control unit.

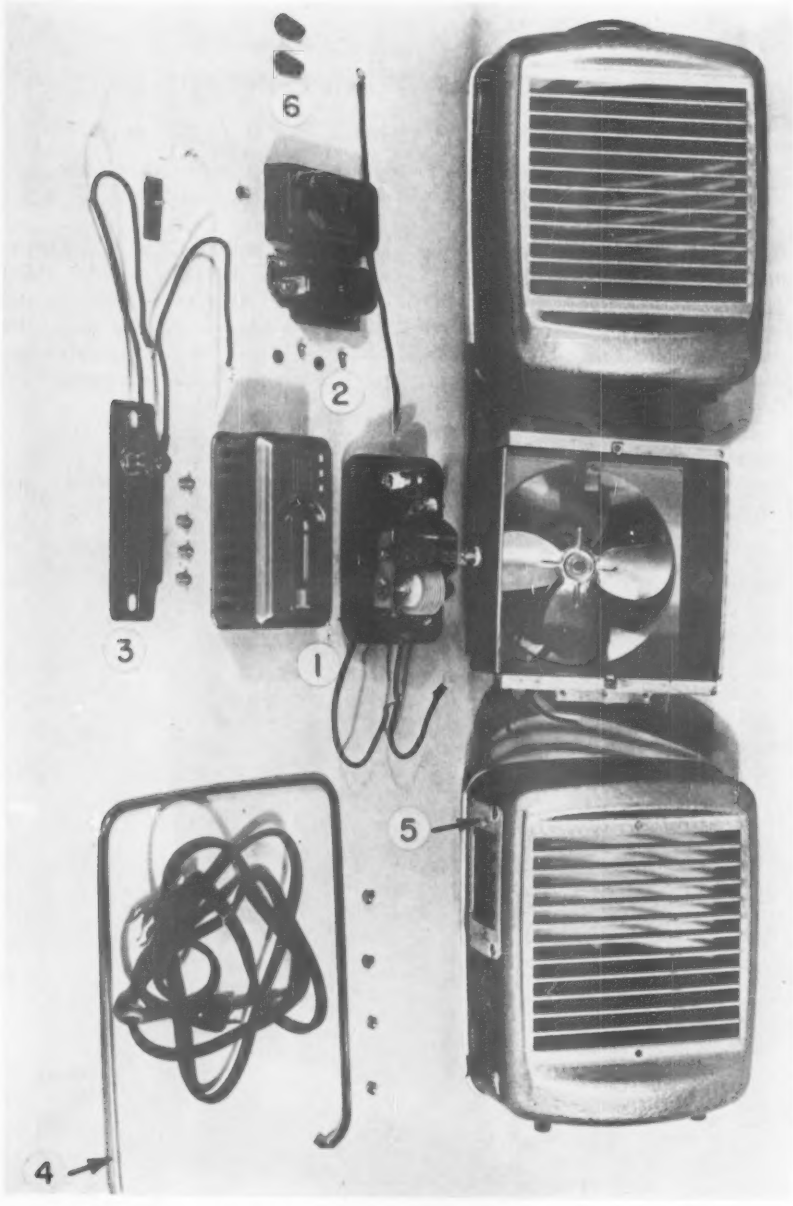

FIGURE 2.—Details of assembly for constant temperature control unit.

TABLE I.—Bill of Materials for BOD Incubator

Quantity	Description
2	Plugs
1	Electric heater unit: Chromalox No. HF-51, or equal
1	Multi-stage thermostat: Minneapolis-Honeywell No. T42K, range 60–100°F, or equal
1	Strip heater: Chromalox No. PT512, 120 v, 125 w, or equal
1	Wiremold duplex receptacle
2	Wire nuts
4	6/32- × 1/2—long, round head machine bolts and nuts

Disassembly of Electric Heater Unit

The assembled electric heater unit is shown in Figure 1. The following describes its disassembly.

1. Remove metal band. See item 4 in Figure 2.
2. Remove metal screws on top, bottom, and front of heater.
3. Remove heater control switch (not shown) from the front half of the heater and clip the four wires as close to the switch as possible; then clip the two heater element wires as close to the 1,320-w heater element as possible, and clip the two fan wires as far from the fan as possible. Remove the 1,320-w heater from the front half of the heater. Save all wires and screws as these will be used in reassembling the unit. The 1,320-w heater element and switch will not be used.

Assembly of Control Unit

Figure 3 shows the wiring diagram and the following describes the assembly procedure.

1. Mark off, on the side of the front half of the unit and as near to the top as possible, the outline and mounting holes of the face plate for the thermostat (item 5 in Figure 2). Drill 1/8-in. diameter holes for mounting and cut out the inner outline of the face plate. Mount the face plate with two each 6/32- × 1/2-in. long round head screws and nuts.
2. Mark off the mounting holes for the duplex receptacle below the thermostat, with the receptacle positioned as close to the bottom of the unit as possible and clip corner of the receptacle as shown (item 2 in Figure 2), so that the clipped corner will be in the lower right hand position. Drill 1/8-in. diameter holes for mounting and drill a hole large enough to pass two wires adjacent to the clipped end of the receptacle as shown in Figure 2. Mount duplex receptacle with two each 6/32- × 1/2-in. long round head bolts and nuts.
3. Mount the 125-w, 120-v heater unit (item 3 in Figure 2) in the space previously occupied by the 1,320-w heater element. Mount with the terminals on the bottom.

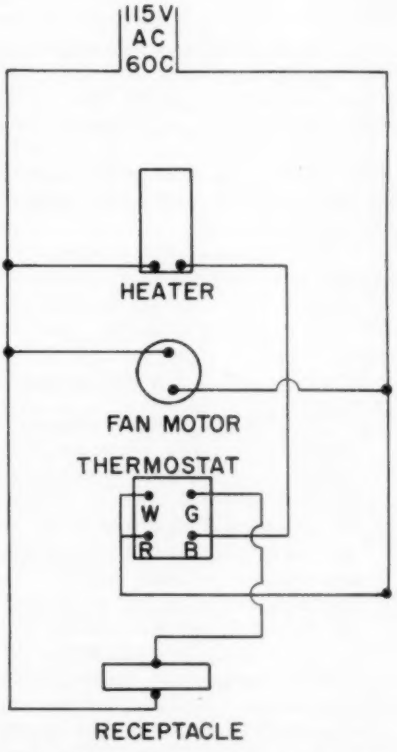

FIGURE 3.—Wiring diagram for constant temperature control unit.

4. Remove cover from the thermostat control (item 1 in Figure 2) and mount the control to the face plate.

5. Connect two 16-gage wires, 12 in. long, to the terminals of the heater.

6. Connect two 16-gage wires, 12 in. long, to the duplex receptacle and pull through the hole at the bottom side of the receptacle.

7. Connect a small jumper wire from terminal "W" to terminal "R" of the thermostat. Connect one 16-gage wire, 12 in. long, to terminal "R" of the thermostat.

8. Connect the end of one wire from the heater to terminal "B" on the thermostat. Connect the end of one wire from the receptacle to terminal "G" of the thermostat.

9. Connect the ends of the following wires together and secure with a wire nut:

a. Wire from terminal "R" on thermostat
b. One wire from fan
c. One wire from line cord

10. Connect the ends of the following wires together and secure with a wire nut:

a. Wire from fan
b. Wire from heater
c. Wire from receptacle
d. Wire from line cord

11. Replace the fan and heater element into the front section of the unit with two metal screws.

12. Join the front and rear sections together with metal screws at top and bottom.

13. Replace metal band.

Installation

1. Place the control unit on the shelf inside refrigerator in an upright position.

2. Drill a hole through the refrigerator box so that the cable from the refrigerator can be plugged into the receptacle on the side of the control unit.

3. Pass the cable from the control unit out the same hole to any 120-v AC power supply.

4. Set the control for the desired temperature.

Cost

The estimated cost of this unit, excluding labor, is approximately $50.

RESEARCH FELLOWSHIPS

Rutgers University has announced a number of opportunities for research fellowships. Some are available for M.Sc. and Ph.D. degree candidates in chemistry, engineering, and biology; and others are available for Post-Doctoral work in chemistry and biochemistry. Investigations for advanced degrees are in air, water, and stream sanitation; reactions and transformations, chemical and biological environmental problems; and radioactive tracer studies. Post-Doctoral fellowships include basic investigations in air and water sanitation; environmental hazards; physical, chemical, and biochemical transformations; and radioactive tracer studies. Stipends are $2,262 for 12 credit hours to $3,393 for 9 hours per semester for graduate study and $6,000 per year for Post-Doctoral work. Free tuition. Research used for advanced degrees. One month vacation. Open to U. S. citizens only. Available Feb. 1, July 1, and Sept. 1, 1961. Include personal data in first letter. Write: Dr. H. Heukelekian, Chairman, Dept. of Sanitation, Rutgers University, New Brunswick, N. J.

Industrial Wastes

EFFECT OF WHEY WASTES ON STABILIZATION PONDS

By T. E. Maloney, H. F. Ludwig, J. A. Harmon, and L. McClintock

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In September 1958, El Centro, Calif., placed in operation a sewage treatment plant consisting of primary clarification with separate sludge digestion, the clarifier effluent being introduced into ponds for aerobic stabilization.

Figure 1 is an aerial view of the plant. The center portion of the photograph shows the three stabilization ponds surrounded by irrigated farm lands. In the lower left center are the two primary clarifiers and two sludge digesters. To the right are four sludge drying beds.

The three ponds cover an area of 50 acres and are operated in parallel. When the plant began operation, the sewage loading was considered to be primarily domestic in origin, with no significant industrial contribution. The city has a population of approximately 18,000 and the sewage flow varies from 1.5 to 2.0 mgd. When the plant was first placed in operation, the 5-day BOD after clarification was approximately 210 mg/l. Thus the stabilization ponds received a BOD loading of between 50 and 70 lb/acre/day. (1.15 and 1.61 lb/day/1,000 sq ft). The sewage usually contained sulfides (2 to 7 mg/l), and its only other unusual characteristic was a high total dissolved solids content of approximately 3,000 mg/l which was primarily sodium chloride. The city's water supply is taken from the All-American Canal (Colorado River water) and has total dissolved solids and sulfate concentrations of approximately 730 and 280 mg/l, respectively. In June 1959 the total dissolved solids content of the sewage dropped to about 1,500 mg/l. This drop was coincidental with a rise in air temperature to a steady daily maximum of about 100°F and with an increase in the total daily flow; thus indicating that the salt pickup was probably caused by infiltration of ground water into the sewers.

In general, the climatic conditions appeared to be ideal for the operation of stabilization ponds. Sunlight is abundant throughout the year, with only occasional cloud cover. During January, the coldest month, the 40-yr average maximum temperature is 79.6°F and the minimum, 28.7°F. The average maximum and minimum temperatures during July, the warmest month, are 113.7°F and 66.1°F, respectively. During this 40-yr period the average annual rainfall was 3 in.

Trouble with Plant Operation

In December 1958, or about three months after the sewage treatment plant was placed into operation, odors were noticeable in the vicinity of the ponds. At about the same time an intense formation of gas bubbles was

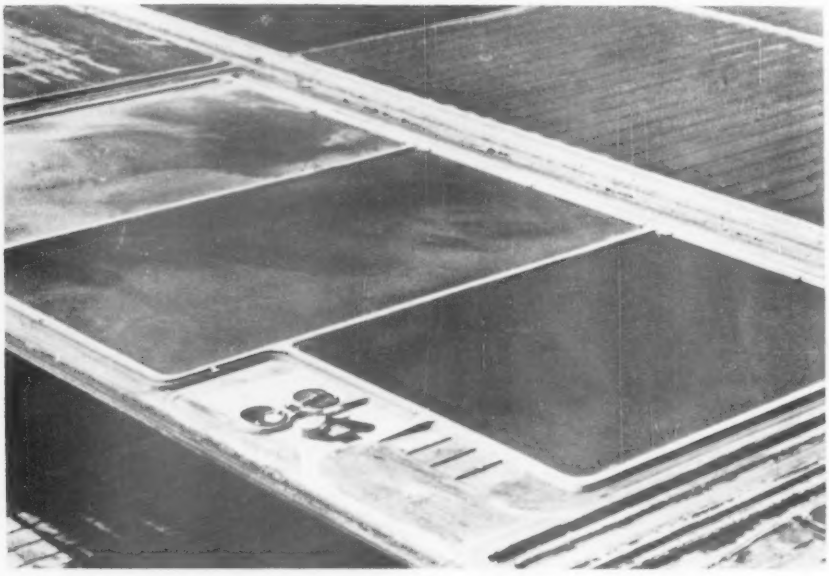

FIGURE 1.—El Centro's treatment plant and ponds.

noticed in the three ponds and in the influent ditch feeding them. The odor was distinctly that of hydrogen sulfide and apparently was derived, at least in part, from the reduction of the sulfates in the water supply. Shortly thereafter there were reports of the paint on dwellings in the vicinity having been affected by the gas. Early in January a black sludge-like deposit was found to be spread over the bottoms of the ponds. Subsequent analysis proved that the black coloration was due to iron sulfides. The liquid contained an abundance of green algae, primarily *Chlamydomonas*.

Remedial Measures Taken

Addition of Nitrate

The nuisance caused by the odor was such that immediate remedial and preventive measures had to be taken. In the middle of January 1959, about four tons of sodium nitrate powder were added to the ponds by airplane dusting to provide a chemical source of oxygen to prevent rapid reduction of sulfates to sulfides. Nitrate treatment has been successful in preventing sulfide odor nuisances in cannery waste lagoons (1) and in preventing anaerobic conditions in streams (2). This amount of nitrate provided a nitrogen concentration of 20 mg/l, and thereafter sodium nitrate was added to the pond influent to give a concentration of 5 mg/l nitrogen.

The effect of nitrates as a remedial measure was difficult to evaluate. Following their addition, "white clouds" were observed from time to time throughout the ponds. These clouds were later found to be colloidal sulfur. No doubt, the addition of nitrate alleviated the sulfide problem, but did not affect the tendency of the ponds to be anaerobic.

Alterations in Pond Loadings and Depths

In addition to nitrate treatment, alterations in pond loadings were also made, with the flow distributed so as to overload one or more ponds and

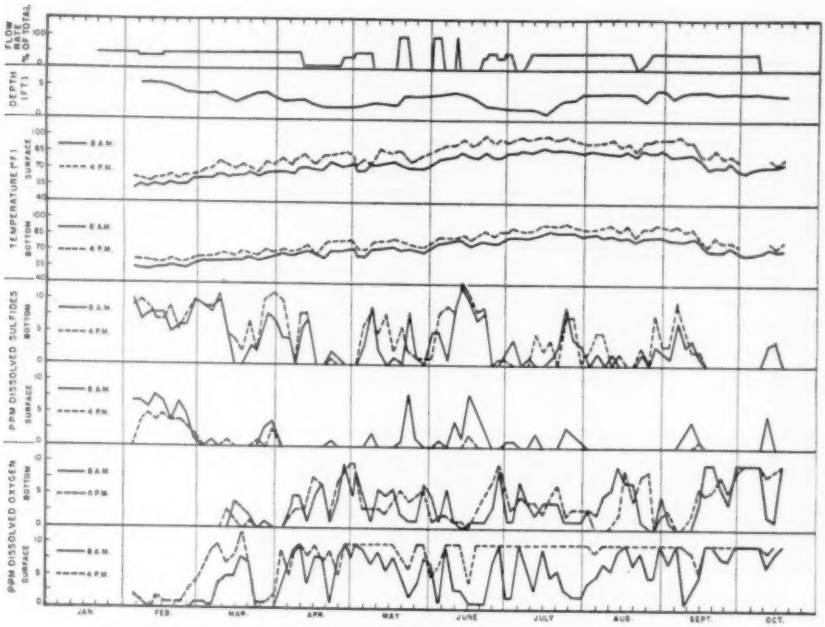

FIGURE 2.—Chemical and physical characteristics of Pond 1, 1959.

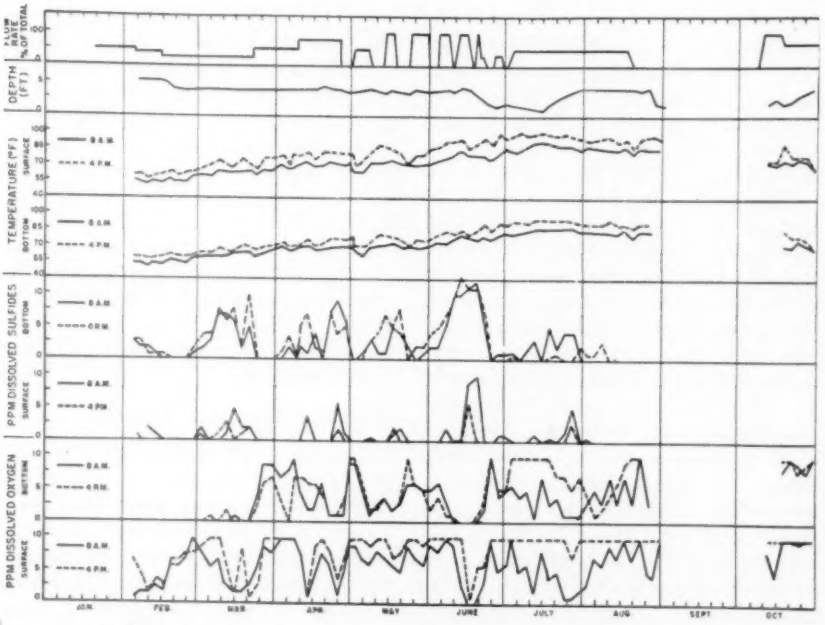

FIGURE 3.—Chemical and physical characteristics of Pond 2, 1959.

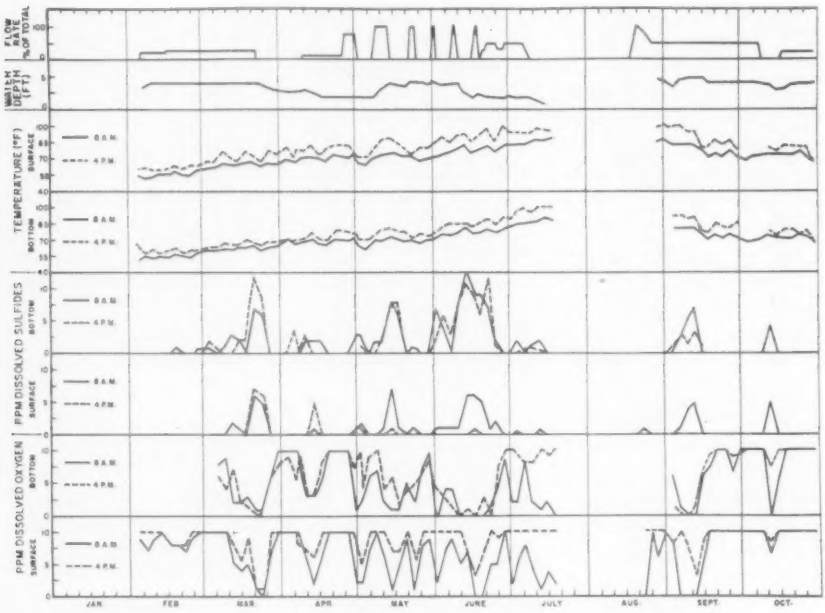

FIGURE 4.—Chemical and physical characteristics of Pond 3, 1959.

underload others. In all cases the effect of overloading was a further deterioration (increase in sulfide production), thus disproving the hypothesis that the ponds might be suffering from lack of sufficient nutrient for good algal growth. Also, in all cases a reduction in loading resulted in a prompt improvement in pond performance, as indicated by a decrease in sulfide production and by an increase in the numbers of species of green algae, such as *Chlorella* and *Scenedesmus*, considered preferable in sewage stabilization ponds (3). When the loading on a pond was stopped, the pond improved gradually and after about two weeks became aerobic throughout its depth. Also, the algal population which became established was predominantly of desirable species. Nevertheless, these rested ponds were not "cured." When normal loading was re-established, they reverted promptly to their previous unsatisfactory condition. All these experiences indicated the presence of some toxic material in the ponds, the effect of which was felt promptly on the re-establishment of loading.

Shifting the loadings among ponds, although not a cure, provided a temporary means for keeping the odors under control. As soon as the pond or ponds being overloaded showed high sulfides, the loading was shifted to the underloaded pond or ponds.

Besides reducing the load on a pond, the depth was lowered in an effort to improve mixing of the top and bottom layers. This procedure was helpful too, but it did not bring about a permanent cure.

Chemical and Algal Analysis

To obtain information on what was happening in the ponds, surface and near-bottom samples were taken at 8 AM and 4 PM at the effluent ends, and concentrations of dissolved sulfides and oxygen were determined. Three-day averages of these measurements from January to October, 1959, and other

TABLE I.—Variation in the Green Algae Populations of the Large Ponds, 1959

Algal Species	Per Cent of Total Organisms Present																															
	Jan.	Feb.	Mar.			Apr.				May			June					July				Aug.				Sept.				Oct.			
	19	26	3	12	24	2	8	22	29	12	19	27	2	9	16	23	30	7	14	21	28	4	11	18	27	1	8	15	22	6	13	20	27
Chlorella																																
Pond 1	—	—	—	—	—	—	—	—	—	—	—	10	30	5	40	60	30	50	95	10	40	40	90	60	30	30	70	50	80	70	100	80	90
Pond 2	—	—	—	—	10	—	—	—	—	—	95	50	60	50	60	20	30	60	70	20	30	30	—	10	40	—	—	—	—	—	—	45	30
Pond 3	—	40	—	—	—	5	—	—	—	—	15	10	—	50	30	60	50	90	60	—	—	—	—	—	90	90	50	70	90	90	10	—	5
Scenedesmus																																
Pond 1	—	—	—	—	—	—	—	—	—	—	—	—	5	—	—	—	—	20	—	5	10	5	—	10	10	60	20	—	10	—	—	—	2
Pond 2	—	—	—	—	—	—	—	—	20	30	—	—	—	—	—	—	—	—	—	15	10	25	20	10	40	—	—	10	—	—	—	45	60
Pond 3	—	10	10	90	60	60	—	—	40	30	30	20	10	25	30	—	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	80
Ankistrodesmus																																
Pond 1	—	—	—	—	—	—	—	—	10	—	—	—	—	5	—	—	—	—	—	—	10	—	10	5	—	—	—	—	Few	—	—	—	—
Pond 2	—	—	—	—	5	5	—	—	—	10	—	—	—	—	—	10	—	—	—	—	10	20	80	75	—	—	—	—	—	—	—	—	—
Pond 3	—	—	—	—	15	10	—	—	—	5	15	10	20	—	—	—	2	—	—	—	10	20	80	75	—	—	—	—	—	—	—	—	—
Micractinium																																
Pond 1	—	—	—	—	—	—	—	—	—	—	—	—	—	20	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pond 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	65	—	—	—	—	—	—	—	—	—	—	—	—	—
Pond 3	—	—	—	—	—	—	—	—	5	20	20	—	20	—	—	—	20	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Palmellococcus																																
Pond 1	—	—	—	—	—	—	—	—	—	—	70	10	—	50	50	20	60	30	—	70	30	50	—	—	40	—	—	—	—	—	—	—	—
Pond 2	—	—	—	—	—	—	—	—	—	—	—	50	30	—	—	70	70	—	—	—	30	15	—	—	—	—	—	—	—	—	—	—	—
Pond 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	30	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coelastrum																																
Pond 1	—	—	—	—	—	—	—	—	80	—	—	—	5	20	—	20	—	—	—	—	10	—	—	—	—	10	—	—	—	—	—	—	—
Pond 2	—	—	—	—	—	—	—	—	—	10	—	—	—	20	—	—	—	20	—	—	—	10	—	—	10	—	—	—	—	—	—	—	—
Pond 3	—	—	—	—	—	—	—	—	—	10	10	40	10	25	30	—	20	—	—	—	—	—	—	—	—	—	20	10	—	—	—	—	—
Chlorogonium																																
Pond 1	—	—	—	—	—	—	10	—	—	—	—	—	—	—	—	—	—	—	30	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pond 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pond 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Euglena																																
Pond 1	—	—	—	—	—	—	—	—	—	90	30	80	40	—	—	—	—	—	—	10	—	—	—	5	—	—	10	50	—	—	—	—	2
Pond 2	—	—	—	—	—	—	—	—	—	—	—	—	—	30	20	—	2	—	—	—	—	—	—	5	—	—	—	—	—	—	—	45	60
Pond 3	—	—	—	—	—	—	—	—	—	30	—	—	30	—	—	—	2	—	—	—	—	—	—	—	—	—	30	10	—	Few	90	—	80
Chlorococcum																																
Pond 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20	—	—	—	—	—	—	—	—	—
Pond 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pond 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlamydomonas																																
Pond 1	90	90	90	90	90	—	—	—	—	—	—	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20	—	—	—
Pond 2	90	90	90	90	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pond 3	90	40	40	—	—	5	—	—	—	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other Green Algae																																
Pond 1	—	—	—	—	—	—	85	Few	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20	—	—
Pond 2	—	—	—	—	70	80	97	Few	50	50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pond 3	—	—	—	—	—	—	Few	Few	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	100	—	—

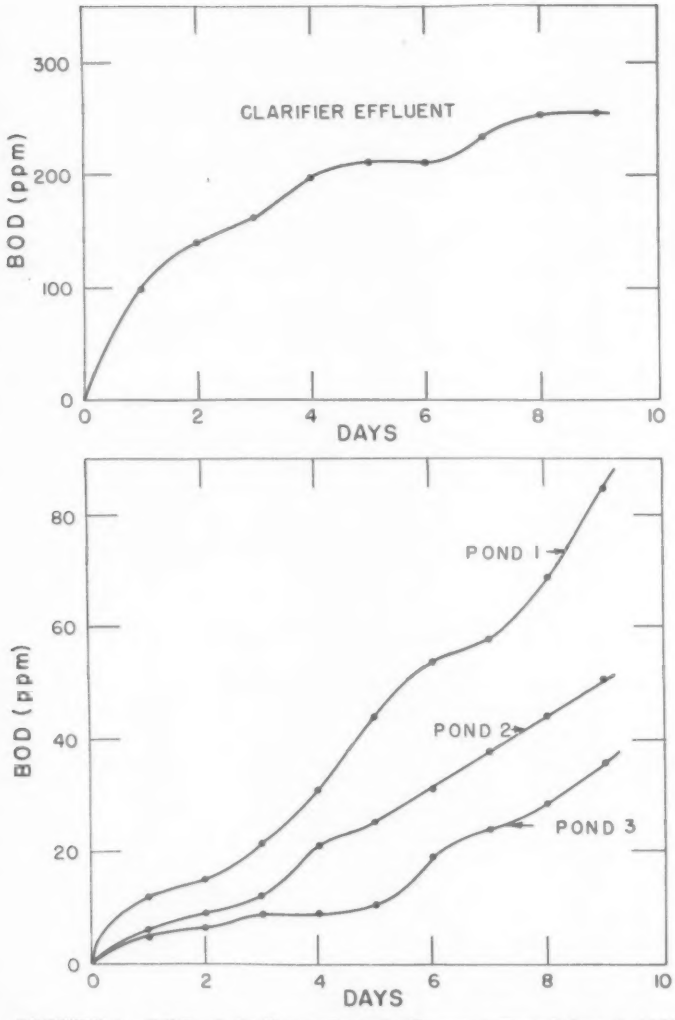

FIGURE 5.—BOD of clarifier and pond effluents collected Apr. 8, 1959.

pertinent information (including pond loadings), are shown in Figures 2, 3, and 4. The DO was determined by color comparison with standards from a field kit, which represented DO concentrations from 0 to 10 mg/l. Therefore, although the DO was often greater, the graphs do not show concentrations over 10 mg/l. Since Pond 2 was dry from September 1 to October 8, and Pond 3 from July 20 to August 20, these data are not included. Samples of the pond effluents were examined weekly to determine the types and approximate quantities of algae present. Table I shows the variation in the green algae population as indicated by the various species in terms of per cent of total plankton organisms present. The presence of diatoms, filaments of blue-green algae, and other microorganisms accounts for the per-

centages of green algae not always being equal to 100. Examination of these data confirms the indication that the ponds were behaving as if they were "sick," and that lessening of the loading and the depth was helpful, but did not enable them to recover fully.

Studies also were made to determine the BOD exertions of the pond effluents when incubated for a long time. Composite samples were taken from each pond and BOD values were determined after an incubation period of nine days. Prior to making the BOD tests, the samples were centrifuged to remove algae and other planktonic forms. Other suspended solids also were removed by the centrifugation. Curves showing the results of these tests are shown in Figure 5.

The clarifier effluent produced a curve of reasonably normal shape with the 5- and 9-day BOD's respectively being 210 and 255 mg/l. The pond samples, however, gave very irregular curves, with the uptake increasing throughout the 9-day period. At two days, the rates appeared to be leveling off at low BOD values, but there was a subsequent sustained acceleration. While the BOD values at 5 days for Ponds 1, 2, and 3 were 45, 25, and 11 mg/l, respectively, there was an increase to 85, 51, and 36 mg/l after 9 days.

In explaining the relative BOD's of the three ponds, it should be noted that Pond 3, with the lowest BOD, had received no influent for two weeks and would be expected to contain less oxidizable material. Pond 1 was just recovering from a period in which algae had been replaced by red sulfur bacteria, and its oxidizing activity had been retarded. From these data it appears that, in spite of the associated problem of sulfides and odors, fairly good treatment was being achieved. Pond 1 showed a 67 per cent reduction in the 9-day BOD of the clarified influent, while the reduction in Ponds 2 and 3, respectively, was 80 and 86 per cent.

Search for Toxic Materials

A search for toxic metals was made by collecting samples of the raw sewage flow composited for eight hours a day over a total period of approximately one week. This series of samples was analyzed by spectrographic methods, and no evidence of heavy metal contamination was found.

To determine whether some toxic material in the city water supply was inhibiting algal growth, bio-assays employing unialgal cultures were carried out. Algal cultures were inoculated into city water, clarifier effluent, and filtered water from each of the ponds. Good algal growth occurred in all the samples except the one from Pond 1. At that time, Pond 1 was in the worst condition and was essentially anaerobic, with high dissolved sulfides. These data indicated that some factor associated with the sewage loadings tended to inhibit algal growth and pointed indirectly to the high sulfide content of the pond water as being responsible for the inhibition.

A comprehensive survey was made of the various industries in the city which possibly could be disposing of materials having a toxic effect on algae. Although the survey revealed that a number of industries were disposing of such materials, it did not appear that any of these would be discharged in sufficient quantities to cause trouble. This survey did bring to light, however, that when the ponds were first put into operation they were filled to a three-foot depth with drainage-ditch water. This water is chiefly derived from runoff from irrigated farm lands and could contain materials which are toxic to the algae. The crops are often sprayed with various chemicals, and in addition, the drainage ditches themselves are treated with weedicides and algicides.

It was learned that in the latter part

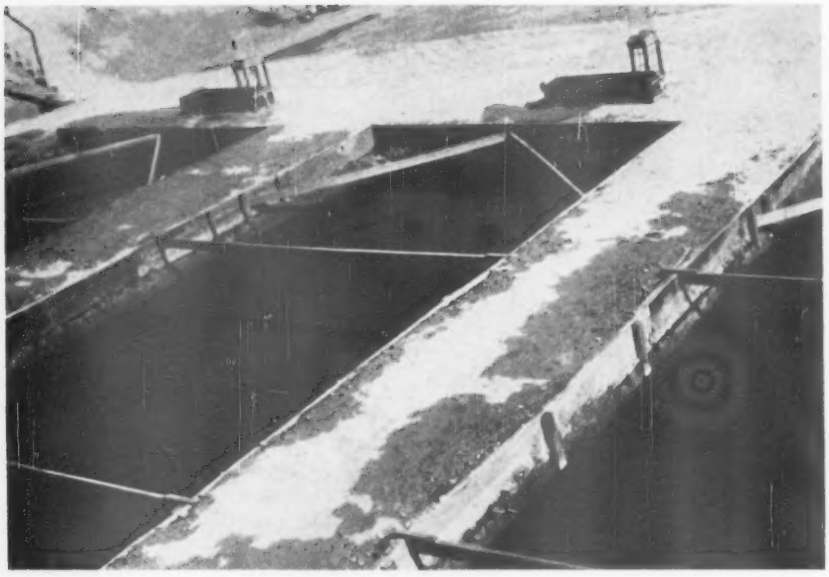

FIGURE 6.—Experimental ponds.

of April, 6,000 gal of whole milk was dumped into the sanitary sewer system by a local dairy. This milk was discarded because of a high content of penicillin which inhibited the starter in making cottage cheese. The penicillin resulted from treating the dairy herd for mastitis. At first it was felt that the penicillin might have been toxic to the algae. But this was the first incident of such mass dumping of whole milk, and the ponds had been operating poorly earlier. Nevertheless, this incident revealed the previously undiscovered fact that large amounts of whey were being continually discharged into the sewer system by the dairy. Over the previous 12-mo period, 12 mil lb of skim milk was used for the manufacture of cottage cheese. The whey resulting from this, all of which entered the sanitary sewer system, amounted to 11.5 mil lb. This was not given immediate attention because even with the whey and domestic sewage the ponds were receiving a 5-day BOD loading of only 50 to 70 lb/acre/day, a loading not considered excessive.

The poor condition of the ponds persisted and in June 1959 the decision was made to construct small-scale ponds where controlled studies could be made. Also, on June 24, 1959, the wastes from the dairy plant were eliminated from the sanitary sewer system. This was done to determine whether these wastes were having a deleterious effect. It was noted that the 5-day BOD of the clarified sewage dropped from approximately 210 to 30 mg/l. But in the early part of the following November, when the flow was decreased, the 5-day BOD of the clarified sewage increased to approximately 100 mg/l, with the dairy wastes still eliminated.

Experimental Studies

Three adjacent ponds were constructed 5 ft apart (Figure 6). Each measured 13 by 40 ft and could be filled to a depth of 4 ft. The ponds were made of compacted earth, chiefly adobe, except for 2 by 12 in. redwood boards rimming the tops. The sides of the ponds sloped at a 45 deg angle from 12 in. below the top to give a flat bot-

tom 5 by 30 ft. The clarified influent sewage, pumped from the distribution ditch to a 50-gal drum, was introduced at the north end of each of the ponds through a 2-in. tee at the end of a 4-in. line. The flow to each of the ponds was controlled by two 1½-in. gate valves arranged in series. When raw sewage was used it was siphoned off prior to clarification and discharged to each of the ponds through a ¾-in. pipe. The outlet was at the south end of each pond and the liquid level in the ponds was controlled by adjusting the level of the structure, a 4-ft standpipe, 4 in. in diam. Two-inch holes were drilled into the standpipe every 6 in. Thus by placing corks in the holes, the liquid level of the ponds could be maintained at any 6-in. increment from 0 to 4 ft. The length of the ponds ran from north to south and they were designated Ponds A, B, and C, from west to east.

Testing Program

Possible test programs were discussed at a meeting of representatives of the participating agencies. These programs included subjecting the sewage to chlorination, aeration, treatment with nitrates and carbon dioxide, varying the depths of the ponds, and employing internal circulation.

The initial plan of approach was to fill Pond A with clarified sewage, Pond B with chlorinated clarified sewage, and Pond C with sewage taken from a large pond.

Pond A was filled with clarified sewage to the 3-ft level on July 13, and after filling, the influent was adjusted to a rate of 30 gph or 720 gpd. Since at the 3-ft level the volume of the pond was approximately 7,200 gal, the detention period was 10 days. Within 72 hr after filling, there was good algal growth, mostly *Chlorella* with some *Chlamydomonas*, and DO throughout the pond. This pond responded so well to the introduction of new sewage that there did not seem to be any advantage in introducing chlorinated sewage into Pond B for comparison. Therefore, on July 16, Pond B also was filled with clarified sewage and within 72 hr it too was in excellent condition.

On July 16, Pond C was filled with supernatant material from large Pond 2 and was allowed to stand without the addition of new sewage. On the morning of July 17, Pond C had 13 mg/l DO at 1 in. and 12 mg/l DO at 25 in. By July 21, the level of this pond had dropped considerably from the 3-ft mark and new clarified sewage was added rapidly to restore the level.

Because of soil absorption, evaporation, and percolation, the ponds had no effluent and the influent was adjusted to a rate of 60 gph in all three ponds. This halved the detention time to five days.

Samples for chemical and algal analyses were taken routinely in the morning and in the afternoon at the 1- and 25-in. depths. Chemical tests included DO, dissolved sulfides, pH, and total dissolved solids. Biological analyses included cell counts and identification of genera present.

On July 22, light-penetration studies were made on the three ponds using matched, surface and submerged phototronic cells sensitive between 4,200 and 7,000 A. These studies were made at 3 PM and the sky was clear. At this time of year at 32.7 deg N. Lat. (El Centro), the visible solar radiation (4,000 to 7,000 A) has a minimum and maximum insolation of approximately 161 and 268 Langleys,* respectively (4). The percentages of light remaining at the various depths in Pond A are shown in Figure 7. The results of the tests made on the remaining two ponds were very nearly the same. The difference in light absorption with depth is for the most part caused by the algae present. The euphotic zone, or that layer absorbing 99 per cent of the light, extended to 24 in. This is generally considered the stratum in

* A Langley equals 1 g-cal/sq cm.

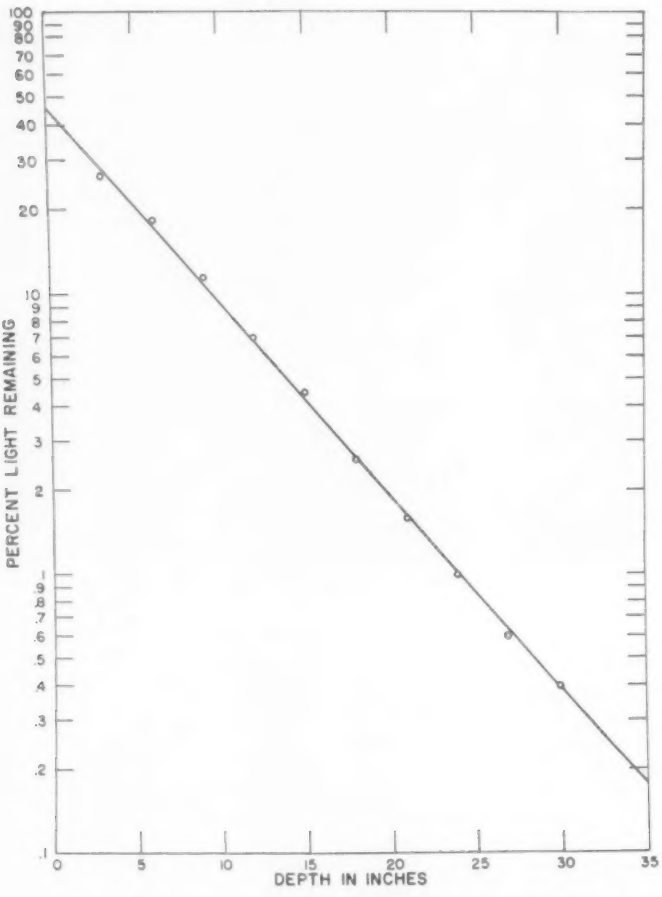

FIGURE 7.—Light remaining at various depths in Pond A (3 PM, July 22, 1959).

which most of the photosynthetic activity occurs.

Test Ponds A and B which had been filled initially with clarified sewage had been functioning in a satisfactory manner for over a week. Hypotheses could be advanced explaining why the test ponds were operating satisfactorily while the large ponds were operating poorly. Perhaps there was some toxic material in the sewage with an accumulative effect and the small ponds had not been in operation long enough for this to be in evidence. Also, the large ponds had been filled originally with drainage-ditch water, while the small ponds had not. Although the test pond which had been filled with the supernatant material from a large pond had been operating well, perhaps some toxic material derived from the ditch water was still deposited on the bottoms of the large ponds and was the cause of the unsatisfactory performance. The only difference in the sewage originally discharged to the large ponds and that now being discharged to the small ponds was the presence of

dairy wastes in the former. The large ponds had not received dairy wastes for nearly a month and they were still not operating satisfactorily. However, the possibility existed that these dairy wastes could be having an accumulative and prolonged effect.

Since this was a fairly brief study and time was limited, a decision was made to determine first the effects of dairy wastes on the performance of a test pond.

Test on Pond A

On July 23, beginning at 4 PM, 5 gal of whey was added to this pond at the rate of 0.5 gph. This time period was chosen to simulate the time at which whey would reach the stabilization ponds after leaving the dairy plant. The whey was added through a feeding device (Figure 8) which consisted of an inverted 5-gal jug with its neck in an aluminum funnel to maintain a constant head. The flow of whey was regulated by an adjustable clamp on the rubber tubing connected to the funnel spout. A T-shaped trap was placed in the rubber tubing to trap curds and prevent clogging of the line. The feeding device was placed over a wooden trough 4 by 1 by 1 ft which received the clarified sewage. By dripping the whey in the trough containing the sewage, a good mixing of the two was accomplished before entrance into the pond.

The maximum loading of the whey into the sanitary sewer system had been 7,000 gpd. Considering the sewage flow to be 2 mgd, the whey would be diluted 286 times. In the test ponds, the sewage influent was 1,420 gpd. Thus, the 5 gal of whey was diluted 284 times and on a volume basis closely approximated the actual loading on the large ponds when at a maximum.

The DO and dissolved sulfide levels in the pond under test conditions are shown in Figure 9. The dashed lines represent the average of samples taken at 1 and 25 in. at 8 AM, while the solid lines represent averages of samples taken at these depths at 2 PM.

On the morning following the addition of the whey to the pond, there was an apparent decrease in DO. That afternoon the whey was again added at the same rate, and on the following morning no DO was found in the pond and dissolved sulfides were found at both sampling levels. There was some buildup of DO that afternoon and whey was again added. The following morning dissolved sulfides were present again at both sampling levels and still were found at the lower level in the afternoon. The same situation was found the following day and the addition of whey was discontinued to allow the pond to recover.

The whey appeared to cause an increase in algal numbers until a population in the order of 7.5×10^6 cells/ml was reached. However, the pond had a yellow-green appearance and the

FIGURE 8.—Device for feeding whey and nitrates.

algal cells (*Chlorella*) were extremely small with heavy cell walls and generally appeared unhealthy.

The rate of sewage influent was decreased to 720 gpd and the pond appeared to be recovering slowly. After five days no dissolved sulfides were present, but the DO levels were low when compared with the other ponds.

In an attempt to speed recovery of the pond, calcium nitrate was added at a concentration of 5 mg/l nitrogen to the influent sewage. The response to the addition of nitrate was evident, and on the morning of August 3 there were over 7 mg/l DO at both sampling levels. The addition of nitrate was continued and the pond appeared to recover completely.

On August 10, whey feeding was resumed, but at the rate of 2 gpd. The nitrate addition was continued at the rate used previously and it was added simultaneously with the whey. This experiment was conducted to determine more definitely how much whey a pond could tolerate and if the simultaneous addition of nitrate increased the tolerance. At the same time, tests were being carried out on Pond B to determine the whey loading limit in the absence of nitrates.

Whey added at the rate of 2 gpd appeared to have an ill effect on the pond, and on the morning of August 15, dissolved sulfides were found at both sampling levels. However, the condition of the pond improved after this, and although the DO levels were never high, especially in the morning samples, dissolved sulfides were not found. On August 24 the whey loading was increased to 2.5 gpd and the increase did not appear to have any appreciable ill effect. Thus on August 28, the whey loading was increased to 3 gpd. On September 3, dissolved sulfides appeared at the lower level of the pond in the afternoon, and on the morning of the following day, dissolved sulfides were found at both sampling levels and at the lower level in the afternoon. The loading of whey was stopped, but the nitrate addition was continued. The condition of the pond fluctuated, and although it appeared to be recovering, over 6 mg/l of dissolved sulfides were found at the lower level of the pond in both the morning and afternoon of September 10. This indicated that the whey had induced an accumulation of sulfides on the bottom of the pond, and even with the continued addition of nitrate, sulfides were being produced one week after the whey loading had been discontinued.

Tests on Pond B

As mentioned before, the tests on this pond were conducted to determine how much whey loading could be satisfactorily stabilized in the absence of nitrate. The pond had been performing satisfactorily since it was first filled, and on July 31 whey addition was started at the rate of 1 gpd. The whey was fed to the pond in the same manner as it was fed to Pond A. There did not appear to be any serious ill effects as a result of this loading; therefore, on August 3, the whey addition was increased to 1.5 gpd. Because it was not available, whey was not added on August 6, but since the pond still appeared to be in good condition, the loading was increased to 2 gpd the following day. This loading was continued through August 23. During this period the condition of the pond fluctuated, but was never good. The morning DO levels were consistently low and dissolved sulfides appeared intermittently. On August 24 the whey loading was increased to 2.5 gpd and there was an obvious response to the increase. On the morning of August 25 there were 3 mg/l dissolved sulfides at both sampling levels and on the following day over 7 mg/l dissolved sulfides were present. This condition was accompanied by hydrogen sulfide odor, and the pond was drained on August 27.

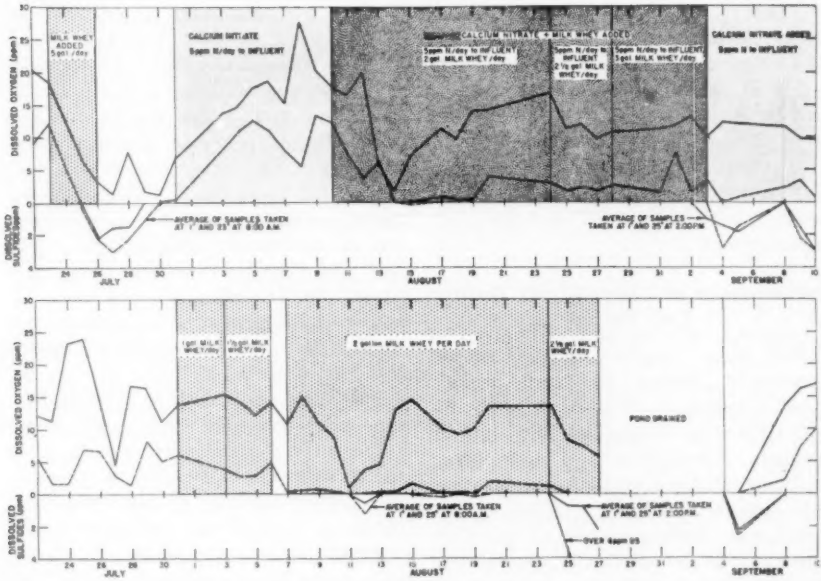
DISSOLVED OXYGEN (ppm)
DISSOLVED SULFIDES (ppm)
MILK WHEY ADDED 5 gpd / day
CALCIUM NITRATE 5ppm N/day to INFLUENT
CALCIUM NITRATE + MILK WHEY ADDED
5ppm N/day to INFLUENT 2 gpd MILK WHEY/day
5ppm N/day to INFLUENT 2½ gpd MILK WHEY/day
5ppm N/day to INFLUENT 5 gpd MILK WHEY/day
CALCIUM NITRATE ADDED 5ppm N to INFLUENT
AVERAGE OF SAMPLES TAKEN AT 1' AND 25' AT 8:00 A.M.
AVERAGE OF SAMPLES TAKEN AT 1' AND 25' AT 2:00 P.M.
JULY
AUGUST
SEPTEMBER
1 gal. MILK WHEY/day
2 gal. MILK WHEY/day
2 gallons MILK WHEY PER DAY
2½ gal. MILK WHEY/day
POND DRAINED
AVERAGE OF SAMPLES TAKEN AT 1' AND 25' AT 8:00 A.M.
AVERAGE OF SAMPLES TAKEN AT 1' AND 25' AT 2:00 P.M.
OVER 4ppm DS

FIGURE 9.—Effect of whey with and without nitrate addition on DO and sulfide levels. Upper curves for Pond A, lower curves for Pond B.

Tests on Pond C

The supernatant material that had been pumped from the large pond had no apparent ill effects on the performance of the small pond. To determine if some toxic substance was deposited on the bottoms of the large ponds, the material from an area 1½ times (0.018 acres) that of the test pond was scraped from the bottom of large Pond 3 and added as a slurry to Pond C on July 28. The large pond had been completely drained July 20 and allowed to dry. The effect of the addition of the slurry was difficult to evaluate. Although dissolved sulfides never appeared, the DO levels were not as high as those in the other two test ponds. However, a few hours after adding the slurry, a yellow-green algal scum began to form over the pond surface. By the following afternoon, this growth, which was identified as *Palmella*, covered practically the entire pond surface. This condition was unfavorable because light was prevented from penetrating to the lower levels of the pond. *Palmella* is a green colonial alga and the cells are imbedded in a gelatinous matrix. Their gelatinous sheaths probably prevented desiccation of the cells when the large pond was allowed to dry and they resumed a viable stage as soon as they came into contact with water again. The algal scum persisted, and finally on August 5 the pond was drained and allowed to dry for a few days.

On August 12 filling of the pond with raw sewage was begun. This was done to find out if the ponds would stabilize raw sewage, and also, if a greater load of whey could be tolerated by a pond when the additional nutrient of raw sewage was present.

Following the filling of the pond, good DO levels were found throughout the pond for several days (Figure 10). On September 4 whey was added to the pond at a rate of 2½ gpd. This whey loading was chosen because it

was that which proved to be intolerable when clarified sewage was employed. The effect was noticeable and the DO levels in the pond decreased steadily and by September 8, dissolved sulfides were present during both the morning and afternoon. The addition of whey was discontinued. Sulfides were still present on September 11, and the pond was drained.

Performance of Large Ponds During Test Period

The large ponds behaved rather erratically during the test period. Pond 3 had been drained on July 20 and allowed to remain dry until late in August. When drained, a heavy layer of black sludge-like material covered the bottom. Although some debris would have been expected, the amount appeared to be excessive considering the length of time the ponds had been in use. Also, this pond had not received as great a loading as the others. Thus it could be assumed that Ponds 1 and 2 would have even more of this material on their bottoms.

After Pond 3 was drained, the sewage flow was diverted equally to the remaining two ponds, and during this time, their depth was increased from 2 to 3 ft. The dairy wastes had been eliminated from the sewer system, but there certainly was not any spontaneous or measurable improvement. The DO and dissolved sulfide levels continued to fluctuate. There were instances of hydrogen sulfide odors, but during the test period these became less frequent.

The ponds appeared to operate in a somewhat irregular cycle. Following a few days of good performance when there were high DO levels through them, large clumps of black material broke off the bottom and rose to the surface. This situation was often accompanied by a decrease in DO, an increase in dissolved sulfides, and in some cases, hydrogen sulfide odor. This same condition occurred after a

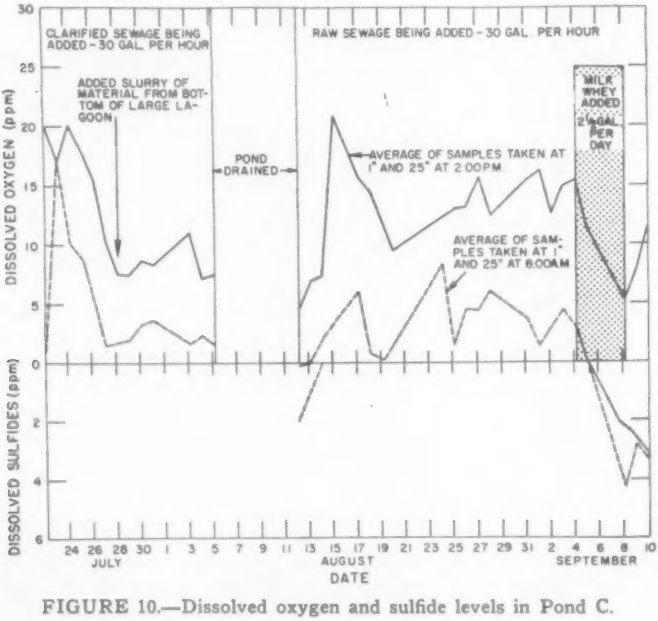
CLARIFIED SEWAGE BEING ADDED - 30 GAL. PER HOUR
RAW SEWAGE BEING ADDED - 30 GAL. PER HOUR
ADDED SLURRY OF MATERIAL FROM BOTTOM OF LARGE LAGOON
POND DRAINED
AVERAGE OF SAMPLES TAKEN AT 1" AND 25" AT 2.00 P.M.
AVERAGE OF SAMPLES TAKEN AT 1" AND 25" AT 8.00 A.M.
MILK WHEY ADDED 2 GAL. PER DAY
DISSOLVED OXYGEN (ppm)
DISSOLVED SULFIDES (ppm)
30
25
20
15
10
5
0
2
4
6
24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10
JULY
AUGUST
SEPTEMBER
DATE

FIGURE 10.—Dissolved oxygen and sulfide levels in Pond C.

few instances of high winds when the pond would appear to turn over. Usually after a day or two the ponds would again be operating in a satisfactory manner; that is, the DO levels would be increased and the dissolved sulfides absent. This was especially true when the ponds had reached the 3-ft level and the clumps of black material were skimmed off with the effluent.

Twenty-four hour composite samples of the influent and effluent were taken from Ponds 1 and 2 on August 18 and 19 for BOD analysis. The 5-day BOD of the influent sewage was 22 mg/l. The effluent from Pond 1 had a 5-day BOD of 41 mg/l with the algae and suspended solids present, and 4 mg/l without them. That of Pond 2 was 35 mg/l prior to centrifugation, and 4 mg/l after. Thus there was over 80 per cent reduction in the BOD if the algae are not considered. This performance compares favorably with pond experience elsewhere (5)(6)(7).

The algal flora of the two ponds varied somewhat, but forms believed desirable were found in each. Most of the algae present belonged to the following genera: *Chlorella, Scenedesmus, Micractinium, Ankistrodesmus,* and *Palmellococcus.* Small amounts of *Euglena* and single filaments of *Phormidium* were found occasionally. The latter were probably broken off from blue-green mats growing on parts of the clarifiers.

On August 19 the entire sewage flow was diverted to Pond 3 to fill it rapidly. There were no odors associated with the filling, and by the time the 3-ft level was reached, DO was found throughout the pond.

Referring to Figures 2, 3, and 4, it is noted that despite the erratic behavior following cutoff of the dairy wastes, the operating ponds (No. 1 and 2), by mid-October, essentially had overcome the effects of the accumulative toxins and had begun to operate in a manner comparable to ponds elsewhere.

Discussion

The tests conducted with the experimental sewage stabilization ponds provided interesting and valuable information. The use of such small ponds to study a problem being experienced in full-scale units many times their size not only proved feasible, but quite desirable. The data obtained revealed that the dairy wastes were the main cause of the difficulties encountered in the operation of the large ponds. Although the dairy wastes had been eliminated from the sewage system prior to the initiation of the experimental studies, there had been no noticeable improvement in the performance of the large ponds. Without employing the experimental ponds, the dairy wastes would not have been singled out as readily as the causative factor. In addition, the test ponds provided for less difficult sampling problems, easy observation, and more flexible experimentation.

The data indicate that the experimental ponds could tolerate a maximum whey loading of 2 gpd, giving a dilution of 1 to 360 with the influent sewage. Even with this loading, the performance was poor. When the loading was increased, the pond definitely became "sick." There is also evidence that the whey had an accumulative effect; thus not even a much smaller loading could be tolerated over a long period of time. Even after the whey loadings were discontinued, a fairly long period of time was required for recovery. This was evidenced more strongly in the large ponds where the residual effects were apparent two months after the dairy wastes had been eliminated from the sewage system. This accumulative effect could probably be traced to a buildup of sulfides on the pond bottom. Large accumulations of these sulfides would not only require large quanti-

ties of oxygen for their oxidation, but also there is the probability that they are toxic to the algae.

The results indicated that a larger loading of whey could be tolerated by the ponds when nitrates were added. Although the nitrates apparently provided some oxygen for alleviating the anaerobic condition, they did not appear to serve as an additional nitrogen source to increase algal growth. The results also indicated that in view of the heavy dosages which would be needed, the addition of nitrates was not practicable.

Whey averages 6.9 per cent total solids consisting of 0.3 per cent fat, 0.9 per cent protein, 4.9 per cent lactose, 0.6 per cent ash, and 0.2 per cent lactic acid (8). The lactose is oxidized rather readily by the bacteria (9) and has a short-term, but high, oxygen demand. The protein molecules are too large to pass through the bacterial cell wall and cannot be used for bacterial growth unless they are first degraded into smaller molecules. To initiate the degradation process, extracellular enzymes must be excreted. Thus, the proteins break down slowly and only small amounts can be oxidized in the stabilization ponds. When large amounts of whey were added, there was probably a large accumulation of proteins on the pond bottom. As the proteins accumulated and slowly broke down, there was probably also an accumulation of sulfates as a breakdown product as well as from the water supply. These, in turn, may have enhanced the growth of sulfate-reducing bacteria; although the data indicate that the normal sulfate content of the sewage, without the whey, did not have an ill effect. Apparently, the sulfur bacteria, which reduce hydrogen sulfide to elemental sulfur, could not keep up with the sulfate-reducing bacteria in their activity and the hydrogen sulfide odor resulted. The iron sulfide found on the bottoms of the large ponds was probably the result of hydrogen sulfide reacting with soluble iron in the sewage. In summary, it appears certain that the whey exerted an accumulative toxic effect on the ponds, but the precise reasons for this are not well understood. The high oxygen demand of the whey lactose and the sulfate formation from the whey breakdown are possibly significant. Also, the presence of nutrients such as those in raw sewage does not appear to enhance the stabilization of whey.

As mentioned previously, the effect of adding bottom material was difficult to evaluate. There does not appear to be any advantage (other than to obtain immediate volume) in filling stabilization ponds with water prior to the introduction of the sewage.

Summary

Experiments were carried out with pilot-plant sewage stabilization ponds to determine why full-scale sewage stabilization ponds, used in conjunction with a primary sewage treatment facility, were not operating in a satisfactory manner. Poor pond performance was indicated by the low concentrations of dissolved oxygen and desirable algae as well as the presence of dissolved sulfides and hydrogen sulfide odors. The test program revealed that the primary cause of the malfunctioning was the whey content of dairy wastes reaching the ponds through the sewer system. The fact that these wastes had an accumulative ill effect on the pond also was determined. The addition of nitrates increased the tolerance of the ponds to dairy wastes in the sewage, but not to any large degree.

Acknowledgments

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OXIDATIVE ABILITIES OF ANILINE–ACCLIMATED ACTIVATED SLUDGE

By George W. Malaney

Assistant Professor, Department of Bacteriology, and Research Associate, Water Resources Center, Ohio State University, Columbus, Ohio

Each year hundreds of new products are developed by the expanding chemical and petroleum industries. During manufacture or refining many side-products and by-products are produced, many of which ultimately end up in the liquid wastes from the process, along with a certain amount of the principal product. Water pollution control authorities are increasingly insistent that each industry exercise some degree of pollution control. Recognizing its responsibility, industry is investing much effort and money in the development and application of suitable methods of waste treatment. One of the most promising methods available for large or small plant operations is the activated sludge process.

Because of the great variety of chemical compounds found in such wastes, it seems that a necessary first step in understanding the success of established methods of waste treatment and in proposing new methods of treatment is the accumulation of basic knowledge concerning the oxidative capabilities of the microorganisms operative in both conventional treatment units and in specially-trained activated sludges. The objective of the present research was a study of: (*a*) the ability of an activated sludge microflora to acclimate to a selected chemical compound representing a basic chemical configuration, specifically aniline (aminobenzene), and (*b*) the capacity of the aniline-acclimated sludge to oxidize other chemical compounds related in structure to aniline.

Materials and Methods

Substrates

With few exceptions the substrates employed in this study were of analytical grade. The exceptions are indicated in the figures by P (practical grade) or T (technical grade).

Diluent

The solution of mineral salts used in preparing the substrate solutions and the activated sludge suspensions for the Warburg runs had the following composition: K_2HPO_4, 500 mg/l; $(NH_4)_2HPO_4$, 325 mg/l; NaCl, 50 mg/l; $CaCl_2$, 50 mg/l; $MgSO_4$, 25 mg/l; $FeCl_3$, 5 mg/l. The solvent was tap water.

Simulated Sewage

The simulated sewage was prepared by mixing in tap water the appropriate volumes of solutions *A* and *B*. Solution *A* was an aqueous solution of glucose and Difco nutrient broth. Solution *B* was a concentrated mixture of the same salts employed in the diluent. The simulated sewage contained the following concentrations: glucose, 500 mg/l; nutrient broth, 500 mg/l; mineral salts, same as in diluent.

Acclimation

The acclimation of the activated sludge to aniline as sole source of carbon and energy was carried out in 1,500-ml aeration tubes by the batch-feed method. Aeration was maintained at a rate sufficient to keep the

solids in suspension. The original source of microorganisms was mixed liquor from the aeration tank of a municipal treatment plant. The sludge organisms were fed simulated sewage until the concentration of suspended solids approximated 2,500 mg/l, then the training program was initiated. This entailed addition of the new carbon source in daily increasing amounts with a proportionate daily reduction of the original carbon source (glucose and nutrient broth). The concentration of salts remained constant. This feeding program continued until, at the end of 20 days, if successful, the activated sludge was utilizing the aniline as sole source of carbon and energy.

Activated Sludge for Warburg Run

The aniline-acclimated microflora was fed and aerated at least one hour before use in the Warburg respirometer. The required volume of mixed liquor was removed and allowed to settle. The supernatant liquid was discarded. The sludge was washed with 100 to 150 ml of tap water. The mixture was allowed to settle and supernatant discarded. The concentration of the sludge suspension was adjusted to 5,000 mg/l by diluting to volume with diluent solution, then was blended for 10 sec to facilitate pipetting.

Warburg Experimentation

The ability of the aniline-acclimated sludge to oxidize compounds structurally related to aniline was tested by the conventional Warburg technique, using 125-ml flasks. Incubation was at 20°C for 120 to 192 hr. Each flask was set up to contain 2,500 mg/l activated sludge solids and 500 mg/l test compound (substrate) in a total volume of 20 ml. Oxidation was recorded as mg O_2 uptake per liter of the mixture in the flask. A control flask for measurement of endogenous respiration was included in each run. Air oxidation and volatility of the substrates were determined by a 24-hr Warburg run in the absence of microorganisms. Results of this run were extrapolated to cover time periods up to 192 hr.

Experimental Results

Acclimation to Aniline

The program of acclimation to aniline was immediately successful, as indicated by an increase in mixed liquor suspended solids. The acclimated sludge was then maintained in a suspended solids concentration range of 4,000 to 10,000 mg/l by batch-feeding every 24 hr with a nutrient solution containing 500 mg/l aniline and the indicated content of mineral salts.

Phenylenediamines (aminoanilines)

The ability of the aniline-acclimated activated sludge to oxidize the phenylenediamines is shown in Figure 1. Structural formulas of the compounds accompany the curves. The phenylenediamines may be considered aniline with a second amino group added to the benzene ring. There are three phenylenediamines (ortho-, meta-, and para-) according to the position of the two substituent groups on the ring in relation to each other. The addition of a second amino group renders the molecule less susceptible to oxidation by the sludge microorganisms. Also, the three isomers vary in their oxidizability. The o-phenylenediamine is oxidized to a greater extent in 192 hr than the p-compound, while m-phenylenediamine is least oxidized.

The control curves represent oxygen uptake by the organisms in the absence of added substrate, i.e., endogenous respiration. Interpretation of endogenous respiration in relation to oxidation of substrate is uncertain. When oxygen uptake in the presence of substrate exceeds the endogenous, it is fairly certain that the substrate is being oxidized. However, when the oxygen uptake curve for the substrate

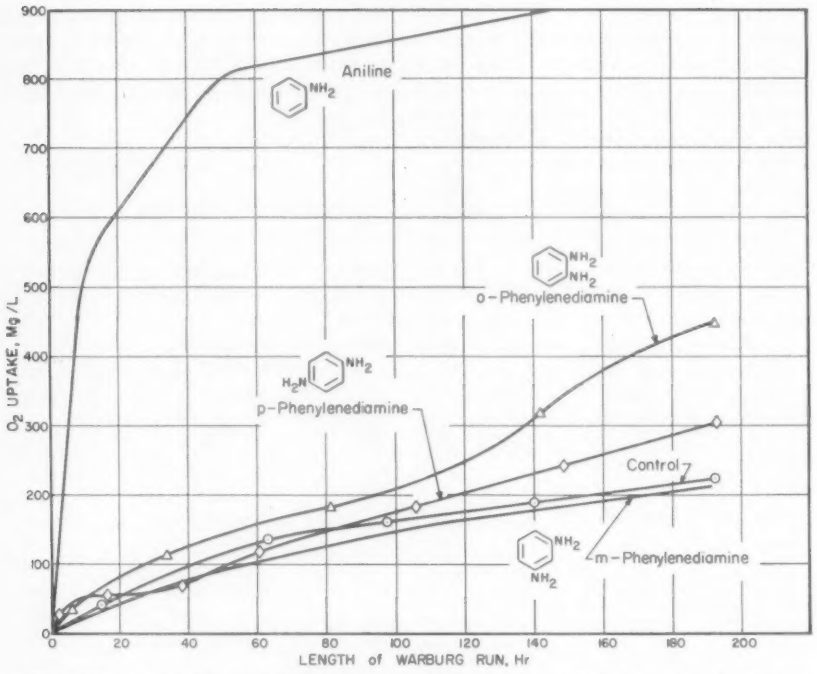

FIGURE 1.—Oxidation of phenylenediamines by aniline-acclimated activated sludge.

falls below that of the control, it indicates either that the substrate is not being oxidized but actually is inhibiting endogenous respiration, or that the substrate is oxidized but at a rate slower than that of the endogenous respiration. This point will be discussed more fully later.

Toluidines (methylanilines)

Replacement of a second hydrogen of the benzene ring of aniline with a methyl group gives the toluidines (o-, m-, and p-methylanilines). Figure 2 shows that these compounds are oxidized as readily by the acclimated sludge as is aniline.

Aminophenols (hydroxyanilines)

Substitution of a second hydrogen of the aniline ring with the hydroxyl group yields the o-, m-, and p-aminophenols. These compounds show a widely divergent susceptibility to biological oxidization (Figure 3). The m-aminophenol was readily utilized, while p-aminophenol was oxidized somewhat less rapidly. o-Aminophenol was oxidized slowly throughout the duration of the run. After a long period of acclimation, phenol was rapidly utilized.

Nitroanilines

Substitution of a nitro grouping on the benzene ring of aniline markedly increased the resistance of the molecule to biological degradation (Figure 4); nevertheless, some oxidation occurred. There was a slight difference in oxidizability between the isomers. Biological resistance increased in the order m-, p-, o-, based on total oxygen uptake. Nitrobenzene was poorly oxidized, if at all.

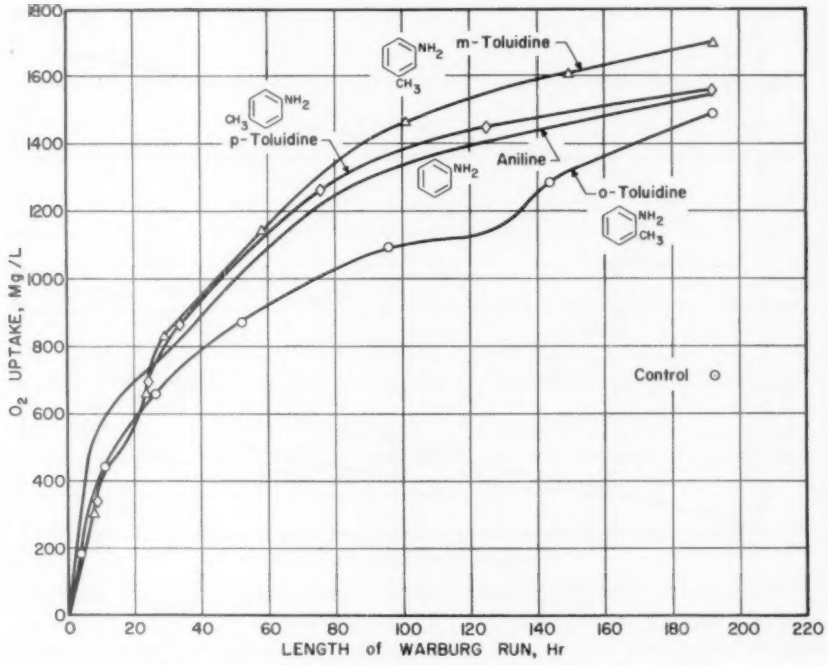

FIGURE 2.—Oxidation of toluidines by aniline-acclimated activated sludge.

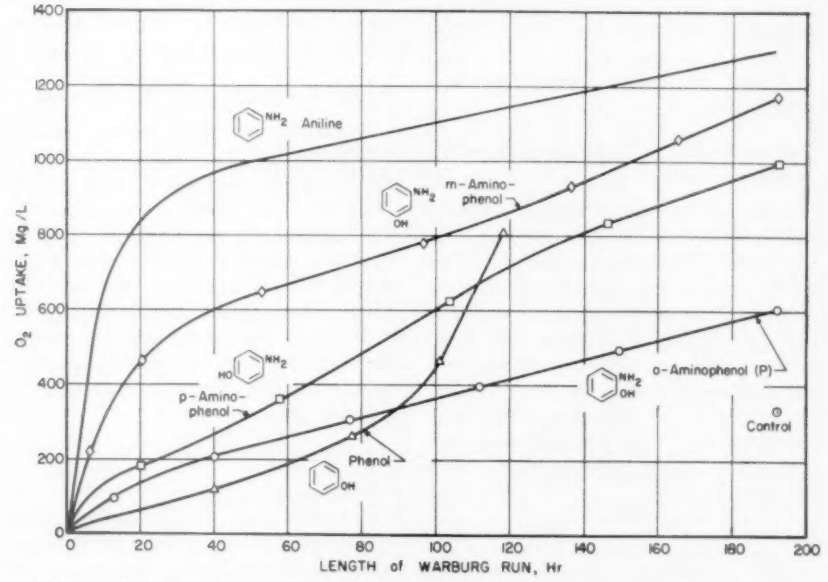

FIGURE 3.—Oxidation of aminophenols by aniline-acclimated activated sludge.

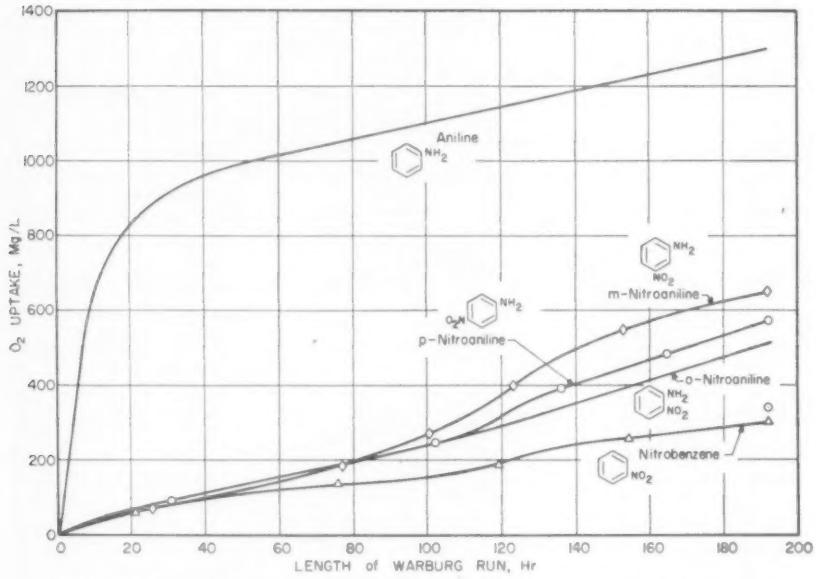

FIGURE 4.—Oxidation of nitroanilines by aniline-acclimated activated sludge.

Chloroanilines

Addition of a single chlorine atom to the ring of aniline also increased resistance to bacterial degradation (Figure 5). Ultimately, the microflora acclimated to the chloroanilines, but oxidation of these compounds was rather slow.

Aminobenzene Sulfonic Acids (aniline sulfonic acids)

Introduction of a single sulfonic acid radical on the aniline ring also produced resistance to oxidation (Figure 6). After five days the microflora acclimated to m-aminobenzene sulfonic acid and began to oxidize this compound rapidly. The microflora acclimated more quickly to the o-isomer, but oxidation of this compound proceeded slowly. The p-isomer and benzene sulfonic acid were degraded with difficulty, if at all.

Aminobenzoic Acids (aniline carboxylic acids)

Substitution of the carboxylic acid radical in a position ortho to the amino group gave a molecule quite easily degraded by the acclimated microflora (Figure 7). However, the m- and p-aminobenzoic acids were relatively resistant to oxidation. Benzoic acid was readily available to microorganisms.

Aniline-Like Aromatic Compounds

Pyridine, cyclohexylamine, and α-naphthylamine have certain points of similarity in structure with aniline (Figure 7). The α-naphthalamine was extensively oxidized in 192 hr. Pyridine was utilized only after a long period of acclimation. Cyclohexylamine, while apparently differing but little from the structure of aniline, was nevertheless not readily oxidized by the sludge organisms in the time interval used.

N-substituted Anilines

Substitution of one or both of the hydrogen atoms of the amino group of aniline with a hydrocarbon radical reduced the oxidizing ability of the molecule as compared with that of aniline (Figure 8). However, each of

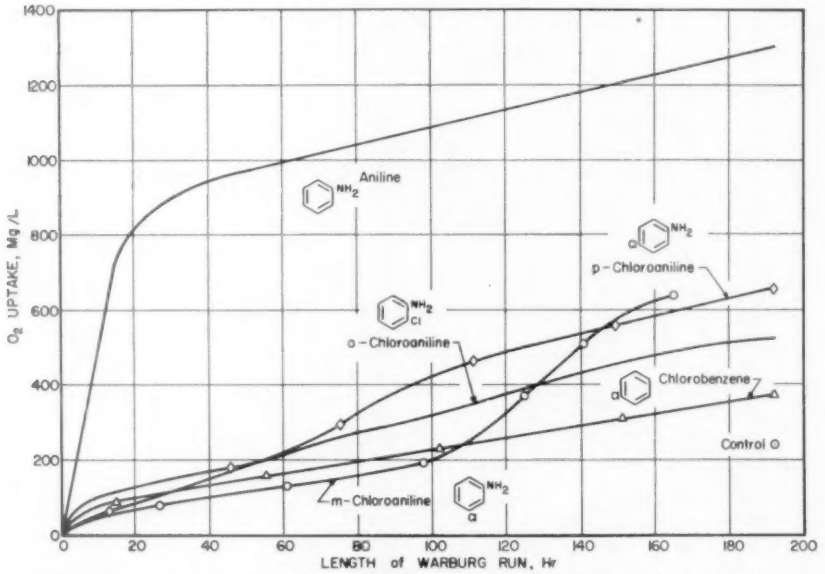

FIGURE 5.—Oxidation of chloroanilines by aniline-acclimated activated sludge.

these substrates was attacked by the aniline-acclimated microflora. Replacement of a hydrogen of the amino group with another amino group yielded a molecule (phenylhydrazine) which was appreciably more resistant to biological oxidation than aniline (Figure 9). Substitution of more com-

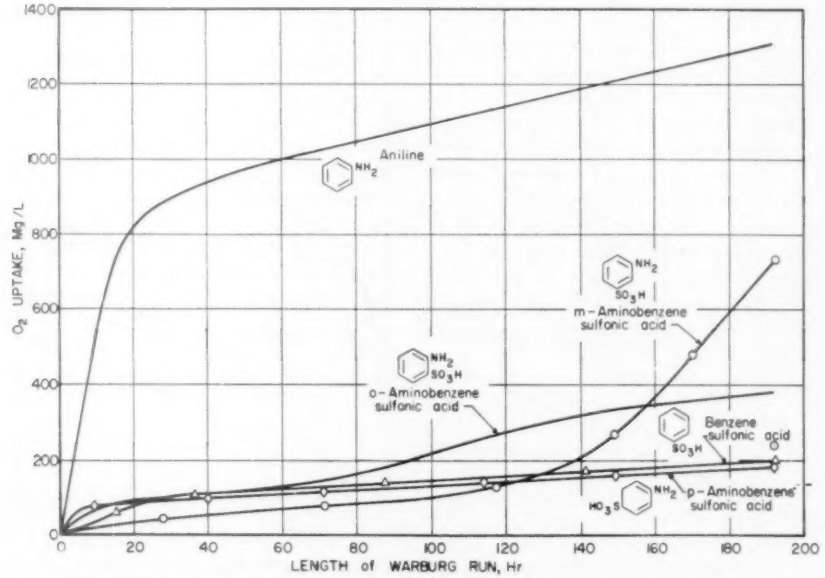

FIGURE 6.—Oxidation of aminobenzene sulfonic acids by aniline-acclimated activated sludge.

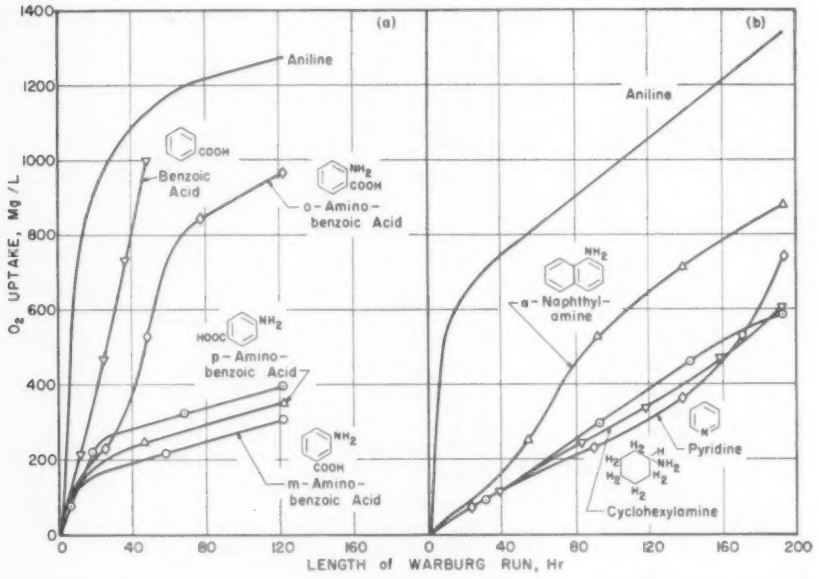

FIGURE 7.—Oxidation of (*a*) aminobenzoic acids and (*b*) aromatic compounds with certain of the structural features of aniline by aniline-acclimated activated sludge.

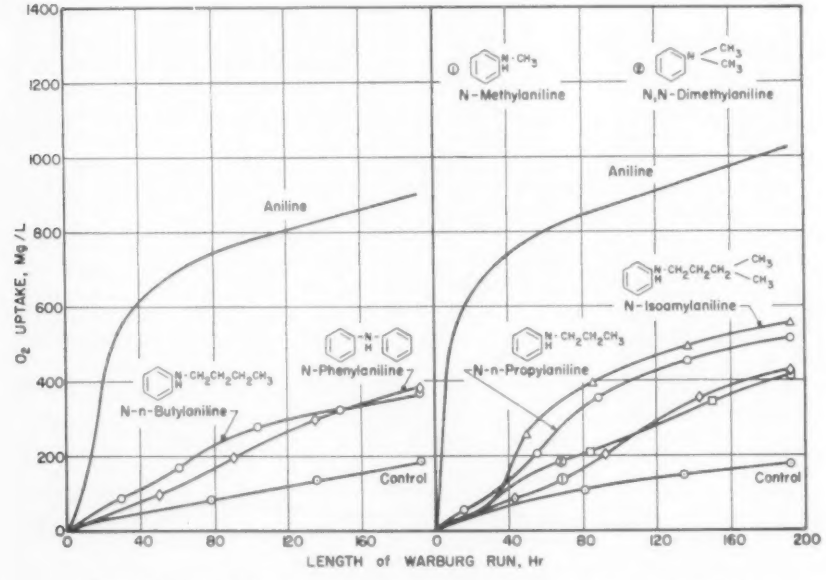

FIGURE 8.—Oxidation of N-substituted anilines by aniline-acclimated activated sludge.

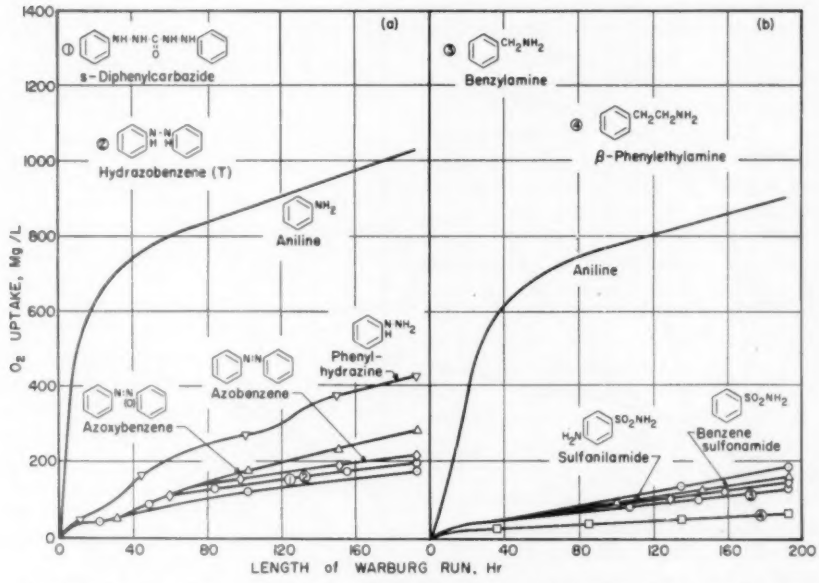

FIGURE 9.—Oxidation of (*a*) N-substituted anilines and (*b*) compounds formed by substitution between the amino group and the ring of aniline by aniline-acclimated activated sludge.

plicated radicals on the N of aniline gave structures which were not readily utilized by the aniline enzyme system (Figure 9).

Substitution Between the Amino Group and the Ring of Aniline

The presence of one or two carbon atoms between the ring and the nitrogen of aniline gave molecules which were quite resistant to oxidation by the aniline sludge (Figure 9). Presence of the SO_2 group in a similar position also retarded bacterial oxidation.

Aniline with Alkyl Substitution on the Ring

Figure 10 shows that substitution of a hydrocarbon chain on the aniline ring reduced to some extent the susceptibility of the molecule to biological oxidation, but nevertheless these compounds were fairly readily oxidized. Unfortunately, only a few compounds of this type were available for testing.

Toluene and the Xylenes

Toluene and p-xylene proved to be readily utilized by the aniline-acclimated microflora (Figure 10), while o- and m-xylene were poorly oxidized, if at all.

Hydroxybenzenes

With the exception of hydroquinone, the mono-, di-, and trihydroxybenzenes tested were susceptible to biological oxidation (Figure 11). The monohydroxytoluenes (o-, m-, and p-cresols) were readily utilized by the aniline organisms (Figure 11).

Aliphatic Amines

Of the straight-chain or branched-chain primary amines tested, only methylamine and n-hexylamine showed any appreciable resistance to bacterial attack (Figure 12).

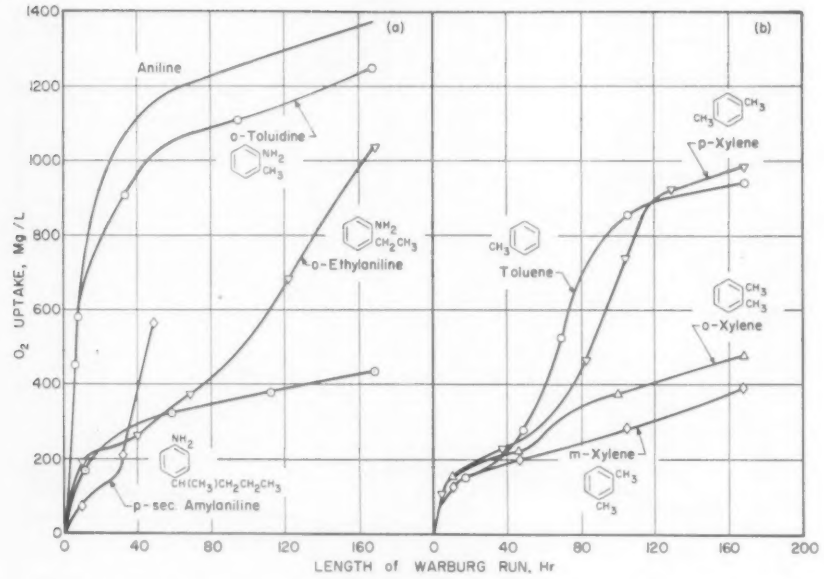

FIGURE 10.—Oxidation of (*a*) aniline with alkyl substitution on the ring and (*b*) toluene and xylenes by aniline-acclimated activated sludge.

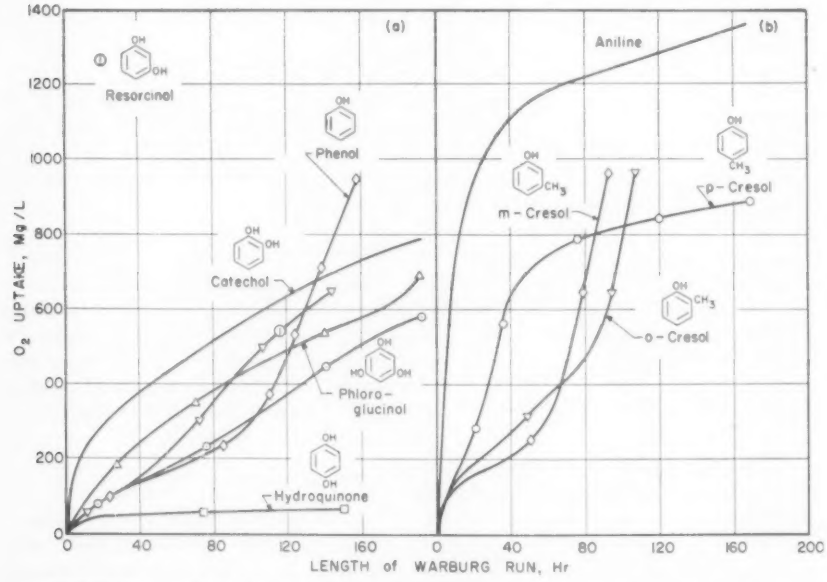

FIGURE 11.—Oxidation of (*a*) hydroxybenzenes and (*b*) hydroxytoluenes by aniline-acclimated activated sludge.

Alkylbenzenes

Figure 13 shows that benzene and all of the mono-substituted alkylbenzenes tested were oxidized to a variable extent by the aniline sludge.

Discussion

The microflora of the aniline-acclimated sludge exhibited an amazing versatility in metabolism possessing an oxidative capacity extending over a broad spectrum of chemical compounds. Of course, it is obvious that this study did not investigate many points of practical importance such as the maximum loading of each substance which the sludge can tolerate, the percentage removal per hour, etc. The experimental results indicate merely that an activated sludge can be acclimated to aniline and that this sludge possesses the enzymatic potential for oxidizing a great variety of compounds related in chemical structure to aniline. The results suggest further that an aniline-acclimated sludge could probably be used as the starting point for the development of a re-acclimated sludge capable of eliminating a specific compound or mixture of such compounds from wastewaters.

As mentioned previously, the significance of the uptake of oxygen ascribed to endogenous respiration (given by the control curves) cannot be evaluated with certainty. Endogenous respiration is usually defined as oxygen uptake by cells resulting from the oxidation of stored food materials. Insofar as activated sludge is concerned, these stored nutrients would include not only those actually deposited within the bacterial cells, but also oxidizable substances making up or adsorbed to the zooglea or slime of the floc particles. During extended periods of starvation, oxidation of vital cell components might also occur. This would be considered endogenous respiration. An important question which has not been answered for all

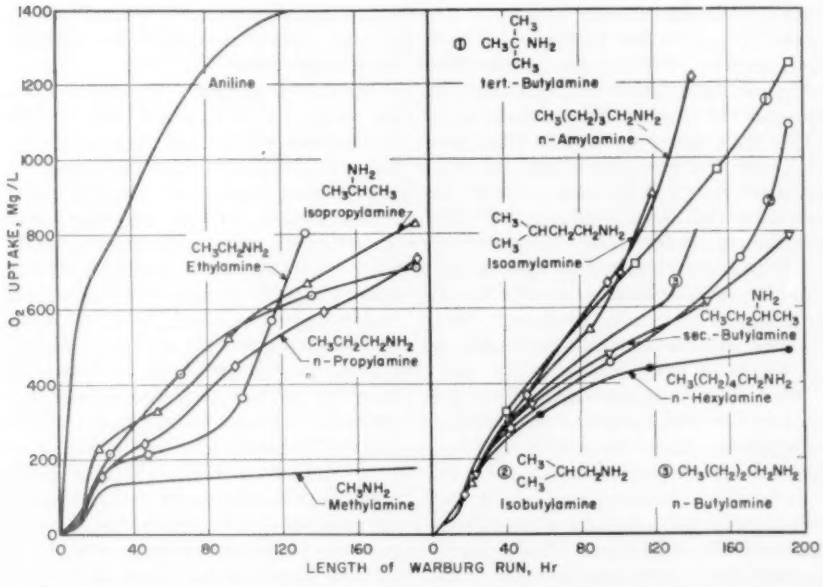

FIGURE 12.—Oxidation of aliphatic amines by aniline-acclimated activated sludge.

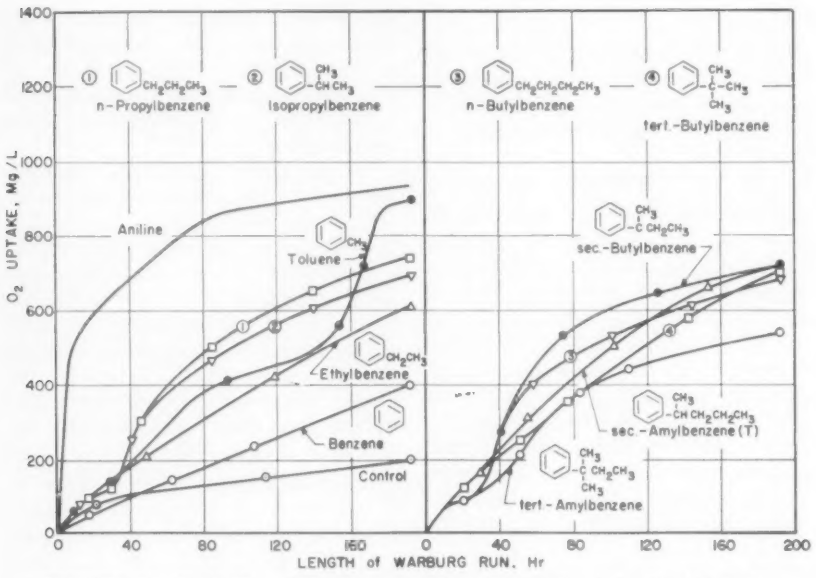

FIGURE 13.—Oxidation of alkylbenzenes by aniline-acclimated activated sludge.

bacteria is whether endogenous respiration continues in the presence of an oxidizable exogenous substrate, i.e., an externally-supplied carbon and energy source. Research has provided the answer for a limited number of microbial species. With some species endogenous respiration continues in the presence of the exogenous substrate, while with other species it does not. There is also the possibility that endogenous respiration may merely be partially inhibited. Moreover, this question probably must be answered not only for each bacterial species, but also for each substrate used. In all it presents a sizable problem. This information for the aniline sludge is not available at this time.

When the oxygen uptake in the presence of the substrate exceeds the endogenous there is apparently no difficulty in interpretation of the data —at least qualitatively. It is fairly certain that the substrate is being oxidized by the organisms. However, if quantitative results are necessary, as, for instance, if percentage removal is to be calculated, then a definitive answer cannot be supplied. Specifically, it is not known whether removals should be calculated on the basis of oxygen uptake data as obtained or on oxygen uptake corrected for endogenous respiration.

When the oxygen uptake curve for the substrate falls below that of the endogenous respiration, there is an additional problem of interpretation. If endogenous respiration does not occur in the presence of that substrate, then the oxygen uptake, however small, must be ascribed to oxidation of the substrate. If endogenous respiration continues unhampered in the presence of that substrate then the lower oxygen uptake in the presence of substrate must be taken to indicate that the substrate inhibits endogenous respiration. If endogenous respiration continues but at a restricted rate along with some oxidation of the substrate, the solution is even more complicated and can be answered only with more detailed experimental methods.

Acclimation curves, such as that of

p-sec. amylaniline in Figure 10, suggests that even though the initial part of the curve is well below the curve for endogenous respiration, some oxidation of the substrate must be occurring. Otherwise it is difficult to explain satisfactorily how the microflora would suddenly begin to oxidize the compound at about 34 hr.

Conclusions

It was possible to train a "normal" activated sludge to utilize aniline (aminobenzene) as sole source of carbon and energy. This acclimated sludge possessed the capacity to oxidize a wide variety of chemical compounds related in chemical structure to aniline, e.g., phenylenediamines, toluidines, aminophenols, nitroanilines, chloroanilines, aminobenzoic acids, aminobenzene sulfonic acids, N-substituted anilines, alkylanilines, alkylbenzenes, hydroxybenzenes, and aliphatic amines.

Acknowledgments

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Stream Pollution

TOXICITY OF ELEMENTAL PHOSPHORUS

By Billy G. Isom

Senior Biologist, Stream Pollution Control, Tennessee Department of Public Health, Nashville, Tenn.

The first objective of this paper is to determine whether elemental phosphorus is toxic to fish in concentrations as low as its solubility, or if the toxicity is due to colloidal P_4, or its oxidation products only. The second objective is to determine the TL_m of phosphorus.

Working with phosphorus, as it relates to stream pollution, in the past has been under the handicap of not knowing the chemical state or concentration of the elemental phosphorus creating a problem as toxicity to fish.

The allotropic solid forms of phosphorus are of three kinds: (*a*) white, (*b*) red (or violet), and (*c*) black (1).

The topic here is white phosphorus tinged with yellow. White phosphorus is a colorless transparent solid (1). It melts at 44.1°C and boils at 280°C. It is very soluble in organic solvents such as benzene and carbon disulfide but only very slightly soluble in water (2). Sidgwick (1) reports: "We have good evidence of the structure of white phosphorus and its vapour. White phosphorus, though its crystal structure has not been determined, is clearly made up of the P_4 tetrahedra which constitutes the vapour at all but very high temperatures; they also compose the liquid, to judge from its Raman spectrum and its X-ray diagram." Although no reference has been found on the toxicity of P_4 to fishes, some toxicological data is available with reference to man.

Published information (3) recognizes the lethal dose for man as 100 mg, and the chronic dose is demonstrated by a daily absorption of 1 mg which causes serious bone and liver damage. Locket (4) states that: "Severe symptoms may follow a dose of phosphorus as small as 15 mg." Of particular interest is the fact that phosphorus causes severe hepatic and renal damage.

Data

A true colloidal suspension is difficult to differentiate quantitatively or qualitatively from a true solution by ordinary chemical analysis. Therefore, a parallel study of the toxicity of soluble P_4 and of colloidal P_4 was made to determine relative toxicities of the two. The method employed to differentiate the two proved to be an effective one. The specific molecular membrane filter * used will retain quantitatively on its surface particles of a magnitude of 0.45μ or greater from a water dispersion. Colloidal particles are usually within the size range of 10mμ to 500 mμ in diameter. Filtering with this type filter removed only partially the P_4 in question. This was revealed by bio-assay when it was observed that the unfiltered solution was more acutely toxic whereas the filtered was toxic but to a lesser degree in similar volume and volume concentrations. Subsequent studies have shown that the above filter could

* Millipore, HA type.

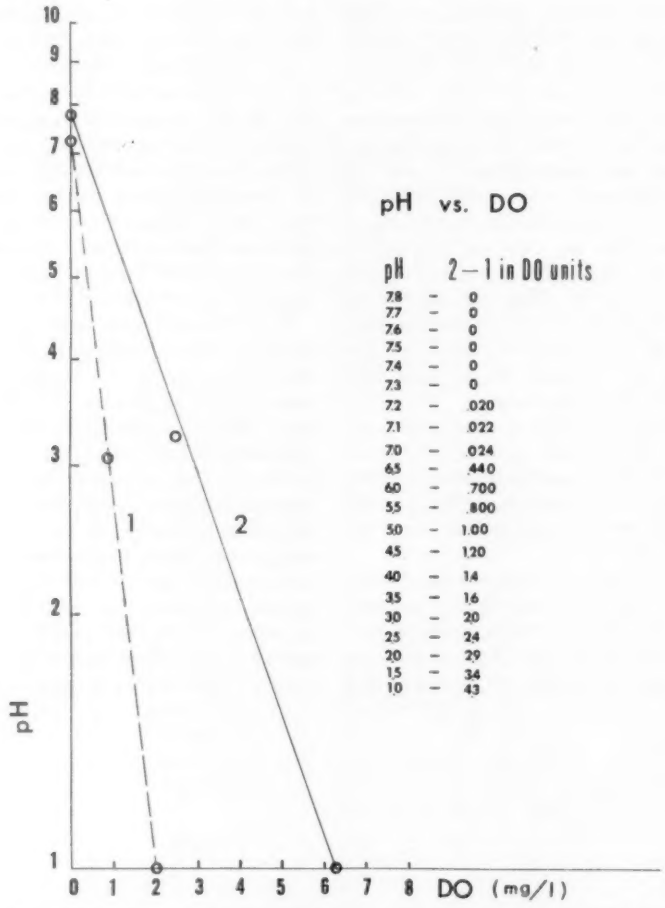

FIGURE 1.—Dissolved oxygen and pH relationship of two samples containing dissimilar concentrations of dissolved oxygen.

not remove the colloid. A special type membrane filter * with 100 mμ pore size diameter, filter diameter 47 mm, was employed to remove the colloid. This filter does remove the colloid as shown by toxicity studies of the filtrate. After the pH is adjusted to approximately 7.0 a 100-per cent concentration of the filtrate shows no toxicity over a 96-hr period. Since the studies on this filtrate were not for the purpose of establishing a TL_m, no controls were used with the studies since 100-per cent survival was obtained in 100-per cent filtrate on preliminary and subsequent studies. All studies for the purpose of establishing a TL_m had adequate controls.

The fish were not appreciably affected by the P_4 (in small concentrations) in the first 24 hr but by 48 hr the fish had begun to die rapidly. Death was undoubtedly due to a physiological inadequacy produced by the phosphorus. As stated elsewhere, in man phosphorus causes severe bone

* Millipore, VC type.

and liver damage. Dissection of the test specimens revealed little macroscopic damage to the liver; however, since these tests are for acute toxicity, it is not surprising that macroscopic examination revealed no gross damage.

In one experiment after the test organisms deceased, additional test specimens were introduced and no die-off occurred over an observed period of six days. A slight decrease in pH (0.7) was noted. This was attributed to the oxidation of P_4. However, lack of die-off was also enhanced by the removal of colloidal P_4 by the first group of test specimens.

Experiments with a saturated solution of P_4 reveal no toxicity when placed in water and filtered to remove the colloidal suspension. The solubility of yellow phosphorus is 0.3 mg/100 ml at 15°C (2).

A stock solution was prepared containing 3 mg/l of soluble P_4, amount of colloid unknown. The distilled water in which a quantity of P_4 was placed had an initial pH of 6.4 to 6.5 but on heating and subsequent cooling the pH of the resultant liquid was less than 4.0 (usually 3.4 to 3.5). Actually, the pH at this point was dependent on the amount of oxygen present initially. The relationship between P_4 and oxygen is shown in Figures 1 and 2. From this stock solution bio-assays were made with the common bluegill (*Lepomis macrochirus*). All test specimens were acclimatized for about 10 days in the proposed dilution water.

Oxidation of elemental phosphorus in water occurs only to the extent of the available free oxygen present initially. During the oxidation reaction complex acids of phosphorus are produced which lower the pH of the solution. The relationship of pH to dissolved oxygen can be found by plotting dissolved oxygen vs. pH of one sample containing a relatively high DO and another plot of pH vs. DO of a sample containing a low DO. Such an example is given in Figure 1. A second curve which shows the DO expected from any pH value provided

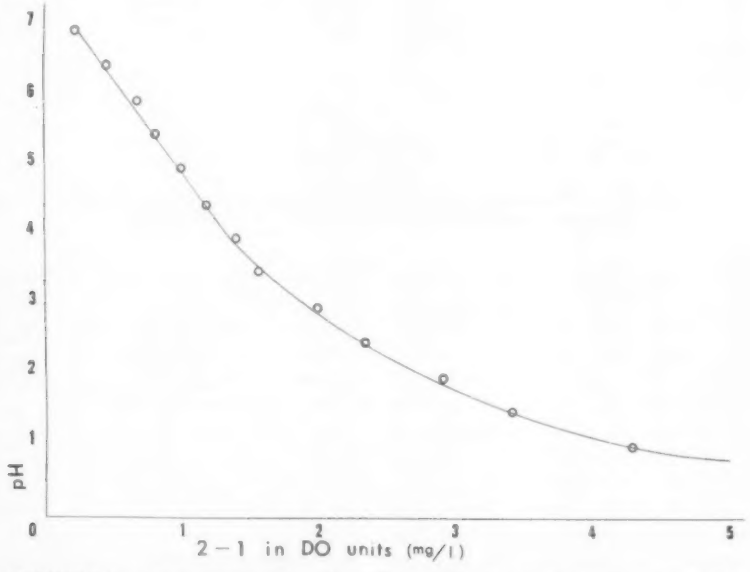

FIGURE 2.—Curve representing the difference in dissolved oxygen at selected values taken from Figure 1.

the initial DO is known is shown by Figure 2. This curve is obtained by plotting the pH vs. the difference in the DO's from the curves in Figure 1.

In order to determine the nature of the toxicity of elemental phosphorus in water to fish the experimental work was begun on the assumption that it was the P_4 in solution rather than the colloidal suspension that produced the mortality in fishes. With the aid of the 100-mμ pore size molecular filter the colloidal suspension could be removed. This was determined by bio-assay of the filtrate which proved to be non-toxic when first neutralized to a pH of approximately 7. The first tests showed toxicity in 100-per cent stock solution but this was due entirely to the low pH incurred as the result of chemical oxidation of P_4 to form complex acids of phosphorus, presumed to be primarily H_3PO_4.

The utility of this study is better understood when these results are correlated with studies of industrial wastes containing the toxicant, elemental phosphorus. Results of studies in 1958 are shown in Tables I and II. Chemical analyses are shown in Table I and the results of bio-assays are included in Table II.

No toxicity was revealed at the low solubility of P_4 in water. Industrial samples were run at 26°C. To determine the solubility at this temperature seemed impractical so an experiment was conducted using the 100-mμ pore size membrane filter. A saturated solution of P_4, unfiltered, was placed in a flask above the membrane and then partially submerged to allow equilibrium to become established between this and the dilution water. Equilibrium was partially forced by adding water to the flask to create a differential. The VC filter used has a flow rate of approximately 3.6 cc/min/sq cm filtered at 70 cm Hg, 13.5 psi differential pressure, and 25°C (5). This shows that it takes appreciable time for 75 to 100 cc to pass by gravity flow through this filter. The time required to do so was not measured but was noted that it required the greater part of 24 hr. This test was conducted in a constant temperature bath, at 26°C. After 144 hr it was noted that all specimens were alive and responding to feeding and otherwise in a normal manner. Thus, elemental phosphorus shows no toxicity at its solubility at 26°C. This is a particularly important factor since all sam-

TABLE I.—Chemical Analyses of 100-Per Cent Phosphorus Water and Dilution Water from One Day in August 1958

Item	Phosphorus Water	Dilution Water
Dissolved oxygen (mg/l)	0.0	6.7
5 Day BOD (mg/l)	—	1.2
COD oxygen consumed (mg/l)	769	195
Apparent color (mg/l)	1,800	100
Turbidity (mg/l)	280	30
pH	5.6	7.2
Methyl orange alkalinity ($CaCO_3$) (mg/l)	1,300	118
Phenolphthalein alkalinity (mg/l)	0.0	0.0
Acidity ($CaCO_3$) (mg/l)	2,870	4.0
Hardness ($CaCO_3$) (mg/l)	0.0	135
Chlorides (mg/l)	—	13
Suspended solids (mg/l)	764	23
Total solids (mg/l)	8,345	155
Settleable solids (ml/l)	0.0	0.0
Sulfates (mg/l)	0.0	17
Phosphates (mg/l)	1,760	2.5
Arsenic (mg/l)	0.0	0.0
Fluorides (mg/l)	2,200	0.6
Centrifuged color (mg/l)	212	0.0

TABLE II.—Number of Fish Surviving After Varying Times in Water Containing Phosphorus, August 18–22, 1958

Time (hr)	P_4 Concentration (mg/l)*																									
	Control	560	490	420	370	320	280	240	210	180	155	135	115	100	87	75	65	56	49	42	37	32	28	24	21	18	15.5
24	10	0	0	0	0	0	0	0	0	1	0	0	0	1	3	6	9	9	10	8	10	10	10	10	10	9	10
48	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	7	9	10	10	10	10	9	10
72	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	6	9	9	10	10	9	9	10
96	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	5	9	9	9	10	9	9	10

* TL_m = 39.5 mg/l.

ples from elemental phosphorus plants were conducted at a constant temperature of 26°C. Three days later the specimens were still reacting normally in the membrane experiment. After completion of this experiment the contents of the flask were poured into the water containing the fish and all specimens were dead within 24 hr.

Discussion and Conclusions

These tests lead to the conclusions that in the consideration of the toxicity of elemental phosphorus in bio-assays with both pure P_4 and industrial wastes containing P_4, the colloidal P_4 is the toxicant within the solubility range of 15 to 26°C. In view of the membrane filter experiment it is readily seen that the ingested P_4 colloid is the active toxicant.

It was concluded from gravimetric tests that the stock solutions did in reality contain P_4 in amounts approximating its solubility at 15°C.

One bio-assay showed a 48-hr TL_m of 0.105 mg/l P_4, a 72-hr TL_m of 0.053 mg/l P_4, and a 163-hr TL_m of 0.025 mg/l P_4.

Another test revealed a 96-hr TL_m of 0.072 mg/l P_4 and a 72-hr TL_m of 0.073 mg/l P_4.

These values fall between the values given as the range of the TL_m.

The bio-assay data given in Table II lists the TL_m as being 39.5 mg/l but from Table I the total phosphates were 1,760 mg/l as PO_4. This means that the TL_m as P_4 is not greater than 0.092 mg/l based on the total phosphates.

As was pointed out by Henderson (6): "With most chemicals, we believe that a true solution rather than a colloidal state is primarily responsible for toxicity." This is certainly true for most chemicals; however, the data obtained here indicate that phosphorus is not toxic at its low solubility. The acids of phosphorus are toxic at a low pH (about five and below) but neutralization with dilute NaOH render them non-toxic. The test solution with colloid removed is non-toxic. The colloidal P_4 is toxic in small quantities at pH's sufficiently high to rule out the complex acids of phosphorus as the toxicant.

The toxicity of colloidal P_4 has not been delineated quantitatively to any specific value but a range of values from 0.105 mg/l P_4 at 48 hr to 0.025 mg/l P_4 at 163 hr have been reproduced well enough to say that the TL_m of colloidal P_4 is not greater than 0.105 mg/l P_4 at 48 hr nor less than 0.025 mg/l P_4 at 163 hr.

Acknowledgments

Appreciation is due the following from the Tennessee Stream Pollution Control Board: Mr. O. D. Keaton, Chief Chemist, for his service and advice; Mr. Ralph M. Sinclair, Principal Biologist, for his assistance with the graphs; and Mr. S. Leary Jones, Director of Stream Pollution Control, for allowing the time and materials with which to conduct the investigations.

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THE OPERATOR'S CORNER

8. SLUDGE CONDITIONING *

The term sludge conditioning as commonly used in sewage treatment relates to a process by which sewage sludge is conditioned or made ready for dewatering on a vacuum filter. A strict interpretation of the term would perhaps include sludge digestion since this process greatly improves dewatering characteristics. Three methods of sludge conditioning are generally recognized: (*a*) thickening, (*b*) chemical coagulation, and (*c*) elutriation. Any one or more of these may be used to prepare the sludge for dewatering on the filter.

The term applies also to thickening of sludge prior to sludge digestion.

8.1 DESCRIPTION OF PROCESSES

8.11 Thickening

Sludge as removed from sedimentation tanks often contains too much moisture to permit economical dewatering. The major purposes of thickening are to remove excess water from the sludge and increase the uniformity of solids.

When sludge is removed from primary sedimentation tanks, either by gravity or pumping, it is not practicable, even with reasonable care, to prevent large quantities of the overlying liquid from flowing through the withdrawal lines. These quantities increase when pumping rates increase and when the sludge fails to move readily to the withdrawal lines.

Sludge from sedimentation tanks following trickling filters or activated sludge units may be low in solids, with moisture well dispersed throughout the sludge mass.

8.111 Gravity:—Primary sludge containing excess moisture possibly may be concentrated by resettling. This is the simplest form of thickening.

Facilities are often provided for withdrawing sludge by gravity from the hoppers of a sedimentation tank to a small adjacent tank. A common method employs a weir in a telescoping section of the sludge-withdrawal line which may be raised or lowered to govern the rate of flow from the hoppers. Before transferring the sludge from this small tank to the digester or vacuum filter, the sludge is allowed to resettle and the supernatant is returned to the sedimentation tank.

Sludge is often stored for a day or even several days in a large holding tank before removal for vacuum filtration. This storage is necessary when (*a*) vacuum filtration lags behind sludge removal, (*b*) or is not conducted daily, or (*c*) when sludge is transported by tank truck to other locations. Simple gravity settling in such tanks followed by decanting of the supernatant often reduces the moisture content substantially.

The increase in solids content by these methods may be as much as 100 per cent. Sludges have been known

* Chapter 8 of MOP 11, *Operation of Sewage Treatment Plants*. Earlier chapters appeared in the September, October, and November issues.

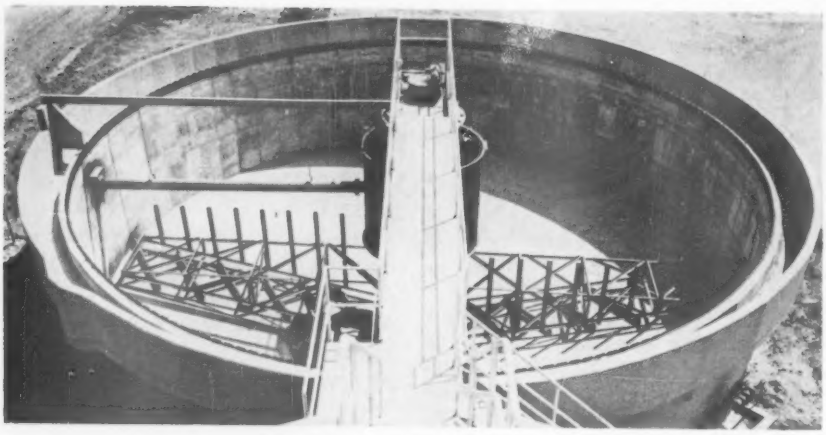


FIGURE 8-1.—Sludge thickener.

to be increased regularly from a 5-per cent solids level to 10 per cent, and sludges with 3 per cent solids have regularly been concentrated to 6 per cent. Not all sludges will behave in this manner without mechanical thickening, however.

Sludge removed from secondary settling tanks usually cannot be concentrated sufficiently by simple gravity methods. For these sludges, mechanical thickening is employed frequently, with or without the addition of primary sludge.

8.112 Mechanical Stirring:—Thickening may be improved by mechanical stirring combined with gravity separation. A common type of thickener consists of a tank equipped with slowly moving vertical sludge paddles or collectors built like a picket fence (Figure 8-1). Most tanks so equipped are circular, although rectangular tanks may be used.

Sludge normally is pumped continuously from the settling tank to the thickener tank which has a detention period of from 2 to 4 hr. The sludge concentrates at the bottom of the tank and is moved mechanically to either the center of a circular tank or the end of a rectangular tank for removal. A blanket of sludge is maintained by controlled continuous removal at a low rate.

To date there has not been enough experience at enough installations to develop a good understanding of operational problems and effective management procedures.

8.113 Pressurized Flotation: — The process involves separation of solids from sludge by applying air under pressure through the sludge mass, with or without the use of coagulating chemicals. The flocculating sludge collects at the surface of the aerated liquid where it is removed by collecting equipment.

Sludge is introduced into a tank, either circular or rectangular, through a line in which air is introduced in fine bubbles. The effluent passes through a small clarification compartment from which a portion of the clarified liquor is recirculated to the inlet pipe. Auxiliary air is introduced across the bottom of the tank. Detention periods in the order of 15 min are common.

To date there has not been enough experience at enough installations to develop a good understanding of operational problems and effective management procedures.

8.12 Chemical Coagulation

When certain chemicals alone or in combination are added to a raw or digested sludge, they form a relatively insoluble floc which agglomerates suspended and colloidal particles.

8.121 Chemicals Used:—Chemicals used have included sulfuric acid, alum, chlorinated copperas, ferrous sulfate, and ferric chloride, with or without lime (Figure 8–2). Ferric chloride probably is the most widely used coagulant. Lime used with ferric chloride precipitates the bicarbonate alkalinity of the liquid fraction of the sludge, reducing the required dosage of the latter. The choice of chemicals often depends on local cost and availability.

Chemicals are thoroughly mixed with the sludge by gentle agitation for 1 to 2 min before the sludge is ready for filtering.

8.13 Elutriation

Elutriation is the washing of digested sludge to remove alkalinity and thus reduce coagulant demand. It is accomplished by mixing the sludge with water or plant effluent for a very short period, often less than 20 sec, using mechanical or diffused-air agitation. The mixture is then settled and the supernatant returned to another plant unit, usually the primary settling tank.

The process may be single stage, multistage, or countercurrent. Often the process is carried out in tanks similar to sedimentation tanks, usually in pairs, in which sludge and wash water enter at opposite ends.

With countercurrent washing, piping and channels are arranged so that wash water entering the second tank comes in contact with sludge already washed in the first tank with wash water coming from the second stage. Thus, there is a counterflow of sludge and wash water. The volume of wash water required may vary from 2 to 10 times the volume of sludge.

The concentration of solids in the sludge from this process may be re-

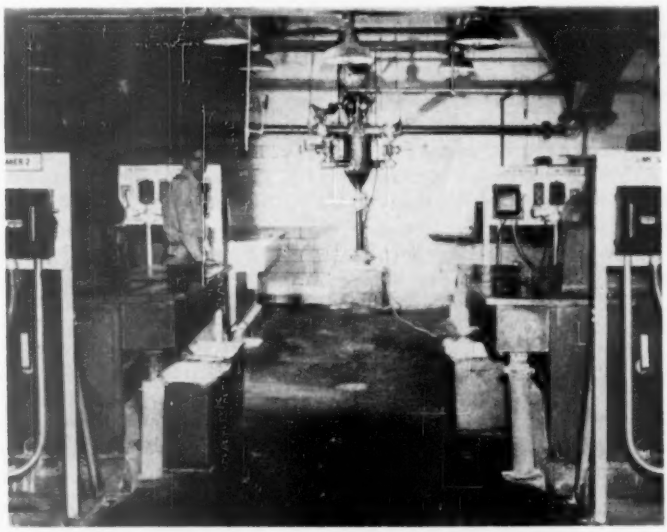


FIGURE 8–2.—Chemical room showing lime slakers and bottoms of storage bins.

duced somewhat, and in that sense, the process serves also as a thickening method.

The process may remove up to 80 per cent of the total alkalinity of the sludge and reduce the amount of ferric chloride required for chemical coagulation by as much as 65 to 80 per cent.

8.2 LABORATORY CONTROL

Laboratory tests and control methods for sludge conditioning and dewatering are auxiliary and directly related to the tests and controls for raw and digested sludge (see Chapters 6 and 7).

The additional tests necessary and useful follow.

8.21 Controls for Sludge Thickening

The principal purpose of sludge thickening is the removal of water. Also important when sludge is vacuum filtered is uniformity of the solids concentration. This permits better control of chemical conditioning.

8.211 Total Solids:—The total solids test should be conducted at least daily on the influent and effluent of the thickening tanks. Where sludges from primary and secondary treatment units are mixed, samples of the mixture should be analyzed.

8.212 Volume and Rate of Flow:—Daily volumes of sludge added to and removed from the thickening units need be known to determine tank performance and loadings on the digester or vacuum filter.

Rates of sludge flow are needed for the operation of concentration tanks whose effectiveness depends on detention time and overflow rates. Volumes and rates of flow for supernatant returned to treatment units should be measured and recorded.

8.22 Controls for Elutriation

The main purpose of the elutriation process is reduction of alkalinity in digested sludge prior to vacuum filtration. Accordingly, the thoroughness of this procedure is best measured by the test for bicarbonate alkalinity.

8.23 Controls for Chemical Coagulation

Control of chemicals for coagulation of sludge prior to dewatering on vacuum filters requires a wide variety of tests depending on the chemicals used, the quality of the sludge, and the type of medium installed on the filter.

8.231 Buchner Funnel:—This test, which simulates the action of the filter, is made to determine the optimum dosage of chemicals to be used, and it should be run often. The test has value for the following reasons:

1. It permits checking the filterability of the conditioned sludge before delivery to the filters;
2. It permits determination of required mixing periods, speed of mixing, and the order of chemical addition;
3. It permits trial of other coagulants without a full-scale filter run;
4. It saves chemical costs by permitting determination of the least expensive effective mixture; and
5. The results may suggest changes in other plant operations which might improve sludge quality.

8.232 Filter Leaf:—Leaf tests are often substituted for the Buchner-funnel test. The filter-leaf test kit permits quite close duplication of actual filter conditions by using a medium similar to the one of the full-sized filter.

8.233 Specific Resistance:—This test is used for the same reasons that the Buchner-funnel test is used.

9. SLUDGE DEWATERING

Digested sludge, even in its most concentrated stage, contains too much water to permit economical or convenient disposal under most circumstances. When this sludge is to be disposed of as a soil conditioner, it is commonly dewatered on sludge drying beds or a vacuum filter. Centrifuging has also been used. Additional moisture may be removed by heat drying, or completely removed by incineration.

Raw sludge requires vacuum filtration, preceded by conditioning, to remove sufficient moisture for economical and convenient disposal. After proper conditioning, it may contain 92 to 95 per cent moisture or even more. Vacuum filtration should reduce the moisture content to about 70 per cent. The sludge cake may then be incinerated if desired.

Drying on sand beds reduces the moisture content of well-digested sludge from a normal range of 90 to 95 per cent to about 70 per cent.

9.1 DESCRIPTION OF PROCESSES

9.11 Sludge Drying Beds

Sludge drying beds commonly are used for small to medium-sized plants, particularly where there is ample area and where there is a good demand for the dewatered sludge as a soil conditioner.

When the digested sludge is deposited on a well-drained bed of sand and gravel, the entrained and dissolved gases tend to buoy and float the solids, leaving a layer of relatively clear liquor at the bottom which drains through the sand quite readily. The major portion of this liquid drains off in less than a day.

After this brief period, evaporation becomes an important part of the dewatering process. As the liquid continues to percolate through the sand and evaporation continues, the sludge cake shrinks horizontally, producing cracks at the surface which accelerates evaporation by virtue of the increased surface of sludge cake exposed to the air.

The beds usually consist of a bottom layer of gravel of uniform size about 1 ft deep over which is laid 6 to 9 in. of clean sand. Open-joint tile underdrains are laid in the gravel layer in a manner which provides positive drainage as the liquid passes through the sand and gravel. The beds may be open to the air or enclosed with glass or other light-transmitting materials in a structure similar to an ordinary greenhouse (Figure 9–1). Evaporation proceeds faster on open beds than covered beds during warm, fair weather, but more slowly during rainy, snowy, or extremely cold weather.

Incompletely digested sludge will not dewater readily on drying beds. Oils and greases discharged with the sludge will seriously retard drainage.

9.12 Vacuum Filters

Vacuum filters are used more often than any other device to reduce the moisture in undigested sludge. Also, they frequently are used to dewater digested sludge in preparation for heat drying or incineration, or before burial or use as fill. Even in small plants, a vacuum filter may be used instead of sand drying beds where (*a*)

FIGURE 9–1.—Covered drying beds.

space is limited, (*b*) odors must be closely controlled, or (*c*) constituents of the digested sludge make drying on sand beds difficult.

If properly conditioned sludge is spread out in a thin layer on a satisfactory filtering material, its moisture content may be reduced greatly and quickly. This principle is used in the construction of a vacuum filter.

9.121 Filtration Equipment: — The vacuum filter (Figure 9–2) is essentially a drum over which is laid the filtering medium, usually a cloth of cotton, wool, synthetic fibers, or plastic, or a stainless steel mesh, or a double layer of stainless steel coil springs. The drum is suspended horizontally so that about one quarter of its diameter is in a vat or trough containing sludge.

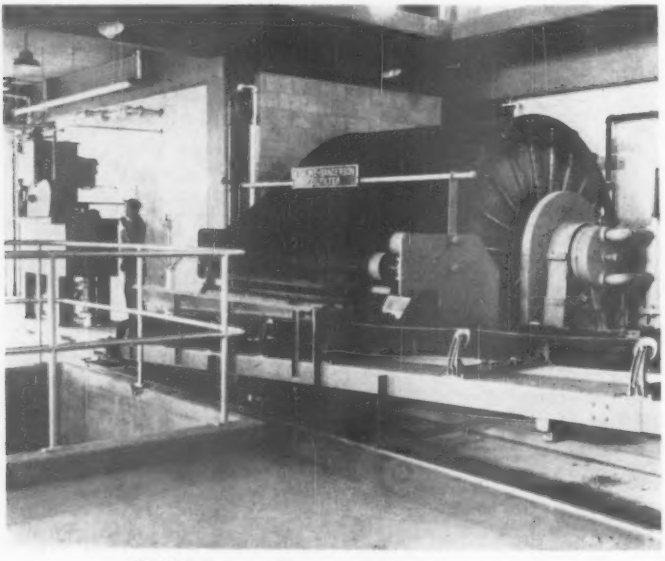


FIGURE 9–2.—Vacuum filter and conveyor.

Valves and piping are arranged to apply a vacuum on the inner side of the filter medium as the drum rotates slowly in the sludge. The vacuum holds the sludge against the drum, and it continues to be applied as the drum rotates out of the sludge trough. This pulls water away from the sludge, leaving a moist mat or cake on the outer surface. The mat is scraped, blown, or lifted away from the drum just before it enters the sludge tank again.

While operating costs, including conditioning of sludge for vacuum filtration, are usually higher than with sludge beds, filtration has the advantages of requiring much less area and it is independent of weather conditions. It may also eliminate the need for digestion, inasmuch as raw sludge can be dewatered sufficiently to be heat-dried or incinerated.

9.13 Centrifuging

Sludge may be dewatered by high-speed centrifuging. The moisture may be reduced to a point where the total solids content of the dewatered sludge is in the range of 65 to 70 per cent.

Frequently, the centrate from this process has a relatively high solids content compared with the filtrate from vacuum filters or the effluent from the underdrains of drying beds. This may impose a serious burden on the treatment facilities to which the centrate is returned.

9.2 MANAGEMENT OF DRYING BEDS

9.21 Preparation

Drying beds should be prepared well in advance of the time a new batch of sludge is to be discharged from the digester. Preparation should include the following work.

1. Remove all old sludge as soon as convenient after it has dewatered sufficiently. Well-dewatered sludge has a cracked, spongy appearance when squeezed and is readily forked. (Figure 9-3). Its moisture content should be no more than about 70 per cent.

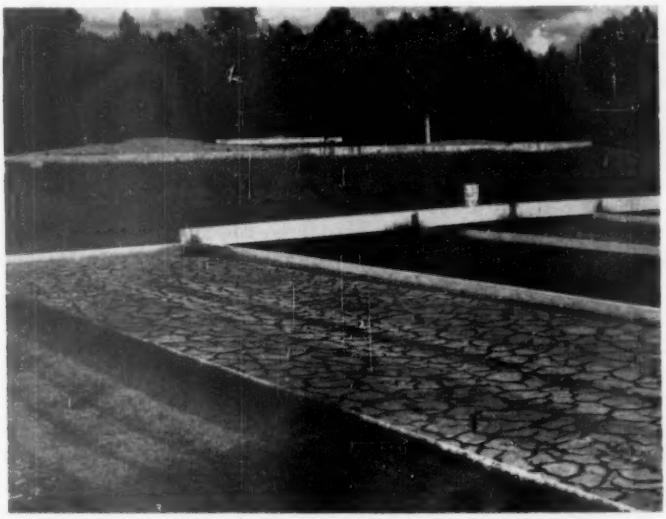


FIGURE 9-3.—Partially dried and wet sludge are in adjacent sections of this open drying bed.

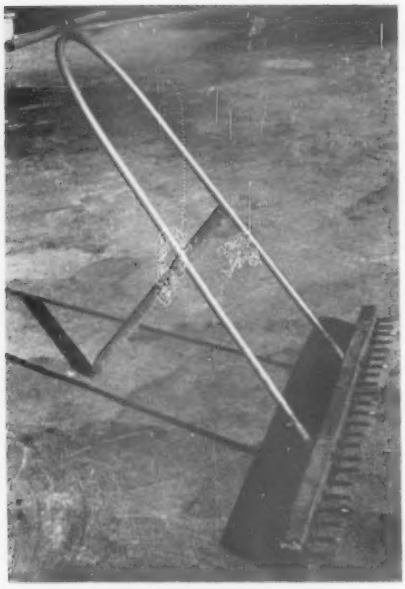


FIGURE 9–4.—Sludge-bed rake.

2. Never add sludge to a bed already covered with sludge.

3. Remove all weeds or other vegetation. Weed killers are generally the most effective if growth is extensive. Otherwise, hand-weeding will be satisfactory.

4. Level the sand and scarify the surface with rakes, spikes, or a spring-tooth harrow (Figure 9–4); relevel just before adding sludge. This reduces compaction of the sand at the surface, thereby improving its filtering ability.

9.22 Replacement of Sand

Replenish the sand to its original depth periodically. Some sand is removed each time the sludge is removed. Clean, coarse sand should be used for replacement. It is a good plan to match as nearly as possible the sand which has proved effective.

9.23 Digested Sludge Quality

Sludge should not be added to the drying beds until it is properly digested. Poorly digested sludge is offensive in odor and dewaters slowly. Sludge that has become "dead" from long-time storage after normal digestion has been completed dewaters very slowly also.

Oils, greases, and other fatty, floating materials will clog the sand and should not be deposited on the beds.

Samples of the sludge should be examined before withdrawal to determine whether it has the characteristics outlined in Section 7.63.

9.24 Withdrawal of Sludge

Sludge should be withdrawn from the digester at a rate sufficiently high to clear the pipeline to the bed. Well-compacted material, including grit, at the inlet end of the line may make rodding or back-flushing necessary. Usually, the valves must be opened fully or nearly so at the start. As soon as full flow is established, the valves should be closed just enough to maintain regular flow. This adjustment should keep the lighter, watery sludge from coning to the pipe inlet.

After sludge has been drawn from a digester, lines should be drained and flushed with water. This not only prevents plugging of the line, but precludes the development of high internal pressures caused by gases generated in the sludge left in the lines.

Caution should be exercised because these gases, when mixed with air, are highly explosive. Open flames and smoking should be prohibited when opening sludge valves on free discharge lines.

9.25 Depth of Sludge

Sludge should be deposited at a depth not greater than 8 to 10 in. With good drying conditions, a well-digested sludge at this depth should dewater satisfactorily and be ready for removal in from one to two weeks.

Sludge high in solids may require up to three weeks or longer unless deposited at a lesser depth.

The volume of sludge ordinarily will be reduced by 60 per cent or more by these dewatering methods.

9.26 Removing Sludge from Beds

The best time to remove sludge from the drying beds depends on:

1. Suitability for subsequent treatment by grinding or shredding,
2. The need to remove the next batch of sludge from the digesters, and
3. The moisture content of the sludge on the beds.

Sludge cake can be removed by shovel or forks at a moisture content of 60 to 70 per cent. But if it is allowed to dry to 40 per cent moisture, it will weigh only about half to two-thirds as much and handle better.

9.261 Equipment Used:—A few large plants have mechanical elevators, conveyors, and loaders, but most operators must use hand tools to lift the sludge from the sand surface. One of the best tools is a shovel-like fork having several tines an inch or so apart, such as an ensilage, coal, or stone fork. With a fork, sludge can be removed with much less sand loss than with a shovel. Nevertheless, some sand will cling to the bottom of the sludge cake, and eventually this sand will have to be replaced.

Many small plant operators use wheelbarrows to haul the sludge from the bed. Planks are laid on the bed for a runway. Wheelbarrows can be placed close to the worker so that the shoveling distance is not great.

Many plants use pickup trucks or small dump trucks. The dump truck has the advantage of quick unloading and most municipalities have them for other purposes. Where trucks are used, it is best to have concrete treadways in the bed wide enough to carry dual wheels; the bed would be damaged if the truck were driven directly onto the sand. The treadways should be spaced so that the distance from any part of the bed to the truck is convenient. If there are no permanent treadways, heavy planks may be placed on the sand.

The crawler trailer with side bins is very popular in larger plants because it can operate on any shape or size of bed without treadways. Less commonly, industrial railways with small dump cars are used.

9.262 Disposal:—The sludge removed from the bed may be disposed of as discussed later or it may be stockpiled and allowed to weather over winter or for several months before disposal. Weathering makes the sludge friable, improving its suitability for disposal for agricultural uses.

9.27 Chemical Conditioning

Usually, no chemical conditioning of sludge is necessary for effective dewatering. But under adverse conditions, certain chemicals are useful. Benefits may be expected when drying beds are inadequate or the sludge's drying characteristics are poor.

Alum has been used successfully in dosages of 1 lb of the commercial grade to 100 gal of sludge. The alum reacts with the carbonate salts in the sludge releasing carbon dioxide gas causing the sludge to float and the liquor to drain out more readily. Drying time may be reduced by 50 per cent or more. To be effective, alum must be mixed quickly with the sludge as it flows to the beds.

Other chemicals have been used with varying degrees of success. Odors may be effectively controlled by adding chloride of lime to the sludge as it is discharged to the beds, but the lime tends to clog the sand. Hydrated lime also is used for odor control.

9.3 MANAGEMENT OF VACUUM FILTRATION

Any discussion of operational controls for vacuum filtration must include the methods and controls used in conditioning the sludge. These controls therefore, are discussed here.

The operator of a vacuum filter is interested mainly in (*a*) good production or yield from the filter, (*b*) economy of operation, and (*c*) a good quality filter cake.

Effective management of vacuum filtration depends on (*a*) the characteristics of the sludge before conditioning, (*b*) effectiveness of sludge conditioning, and (*c*) filter equipment and media.

9.31 Sludge Characteristics Affecting Filtration

Characteristics of the sludge which affect filter yield, economy, and filter-cake quality are:

1. Size, shape, and charge of the solid particles,
2. Solids concentration and volatile content,
3. Chemical composition,
4. Compressibility, and
5. Viscosity.

Each operator must determine within the limitations of his plant and quality of the raw sludge, how he can best control solids content, chemical composition, and some of the physical characteristics.

9.32 Control of Solids Concentration

As discussed in Chapter 8, the solids concentration or percentage of total solids in the sludge may be altered by: (*a*) methods of withdrawal of sludge from settling tanks, (*b*) thickening processes such as mechanical stirring or pressurized flotation, (*c*) elutriation, and (*d*) digestion.

It is generally recognized that filter yields increase as the solids concentrations applied to the filter increase. This relationship is not necessarily proportional, although it may be in some cases. Less conditioning chemicals are required per pound of dry solids for sludges with high solids concentrations.

9.33 Control of Chemical Composition

The chemical composition of raw sludge has a definite effect on the several conditioning processes utilized before filtration. Conversely, many of the constituents affecting vacuum filtration are altered markedly by digestion, elutriation, and chemical coagulation. The demand for conditioning chemicals may be considered in two parts: (*a*) that imposed by the volatile matter in the sludge solids and (*b*) that imposed by the alkalinity of the liquid fraction.

9.331 Volatile Content:—The volatile content of the sludge is reduced by digestion from a level of about 70 per cent of the total solids to 40 to 45 per cent. Other conditioning processes do not materially reduce the volatile matter, except as some of it is lost in the elutriation process or with the effluent from thickening tanks.

9.332 Alkalinity: — The concentration of the bicarbonates of ammonium and calcium, as measured by the bicarbonate alkalinity test, is changed substantially by digestion. Alkalinity measured as a percentage of total sludge solids may be increased from ten- to thirtyfold during digestion.

Alkalinity imposes a demand for coagulating chemicals such as ferric chloride. For this reason, it may be economical to reduce the alkalinity by elutriation. The increase in alkalinity of waste activated sludge during digestion may reach such high levels that the benefit of gas production from

digestion may be more than offset by the cost of conditioning chemicals. On the other hand, undigested waste activated sludge contains a high percentage of moisture which increases the chemical conditioning cost and size of filter required. An alternative is to thicken the sludge without digestion or subject the sludge to elutriation or both. The operator should decide which course to follow on the basis of relative costs.

9.333 Selection of Coagulants:—Many factors must be considered by the operator in deciding which chemicals to use. He might start out by trying those which have been found to be effective elsewhere and experiment with different combinations. In the end, the decision will be made on the basis of availability, effectiveness, and cost. Standard tests using the Buchner funnel, filter leaf, or the specific resistance concept are indispensable in making this decision.

General experience indicates the following relationships:

1. Lime may be used by itself or nearly so for heavy raw sludge, digested sludge, and some dilute, elutriated digested sludge.
2. Ferric chloride and alum are often the most economical combination for sludges of low alkalinity and high solids.
3. Ferric chloride, chlorinated copperas, ferric sulfate, and combinations of ferric chloride and alum are effective on most elutriated sludges.
4. Synthetic polymers show promise of effectively and rapidly flocculating finely dispersed solids.
5. Ferric salts and lime in combination are sometimes effective on waste activated sludge or mixtures of waste activated sludge and fresh sludge.

9.334 Dosage:—The quantity of chemicals required may be estimated from calculations based on the standard tests discussed under laboratory methods. Adjustments frequently need to be made on the basis of filtering performance and quality of the sludge cake.

When using a combination of coagulants, the order of addition and relative quantities of the chemicals are important in terms of performance and cost. For example, it is often more effective and cheaper to use a small quantity of ferric chloride and follow it with a larger dosage of lime.

Overdosages, however, of coagulants may greatly increase the cost without improving filter performance.

High-calcium or dolomitic lime should be used. Magnesium lime is not effective and tends to clog filter media.

9.335 Mixing:—Mixing of coagulating chemicals with the sludge should be thorough and gentle; it is usually accomplished in less than 2 min. The effect of detention time on filtration rate varies with different sludges. Generally, detention periods up to 30 min do not change the filtering characteristics much.

The conditioned sludge should be agitated gently in the sludge vat. Usually, intermittent agitation is most effective, but in other situations, continuous agitation is sastifactory. The operator should experiment to determine the most effective means.

9.34 Depth of Submergence

The operator should try varying depths of submergence of the drum in the sludge vat to find which depth gives the best performance. The amount of overflow from the vat should be kept as low as possible.

9.35 Drum Speed

The higher the drum speed, the greater the yield within the limits imposed by characteristics of the sludge and the filter medium. The operator

should determine the most effective speed by trial and error.

9.36 Vacuum

The higher the vacuum, the greater the filter yield. Normally, a vacuum range of 12 to 15 in. of mercury is effective in terms of filter yield and quality of cake. The small increase in yield for higher vacuums usually does not justify the additional power cost.

9.37 Cleaning Media

All types of vacuum filter media should be cleaned at the end of each filter run to remove the sludge. This is usually accomplished by spraying water directly on the media.

When a filter cloth is so seriously blinded that the filter spray will not remove the sludge effectively, a high-pressure stream from a ¼-in. nozzle sometimes can be used successfully. If this method is not effective, a detergent may be used in combination with a high-pressure stream of water. The detergent is added to water and agitated in the vat which has been thoroughly cleaned. The drum is rotated at full speed for several hours until the sludge is penetrated and softened. The vat is then drained and flushed with water. A high pressure stream of water is used to remove the sludge from the filter cloth.

Metal media are cleaned routinely in a manner similar to that used for cleaning cloth filters. When blinding occurs, the accumulated materials are removed by immersion in acid followed by an alkaline bath.

9.4 LABORATORY CONTROL

9.41 Sludge Drying Beds

Observations commonly made in connection with sludge dewatering on drying beds are those described in the section on digested sludge in Chapter 7. Laboratory tests are seldom performed on the dry sludge removed from the bed. The operator can depend on the extent of cracking, texture, and apparent moisture of the cake to indicate when it is ready for removal.

9.42 Vacuum Filtration

Laboratory tests made on the sludge before filtration are discussed in Chapters 6 and 7. Determinations regularly needed by the filter operator are total solids, volatile content of total solids, total alkalinity, and pH. Special tests include examinations for grease content and toxic metals (if suspected to be present in significant quantities).

Calculations must be made on the amount of chemicals required and used in the filtration process. Filter rates are usually calculated to determine performance.

9.421 Filter Cake:—Principal tests performed on filter cake are those for total and volatile solids. Filter yield is expressed as lb of dry solids filtered per sq ft per hr (psf/hr).

9.422 Filtrate:—The quality of the filtrate may be significant when its solids content and BOD concentration must be kept to a minimum for return to plant processes for further treatment.

10. HEAT DRYING AND INCINERATION OF SLUDGE

The purposes of the heat drying of sludge are:

1. To reduce the moisture content of the dewatered sludge so that its volume is reduced to a practical minimum for convenient and economical disposal;
2. To retain the fertilizing properties of the dewatered sludge;
3. To retain and improve its soil-conditioning properties;
4. To destroy organisms capable of producing disease; and
5. To reduce possible odors.

The purposes of incineration of sludge are:

1. To destroy all organic material, kill all organisms, and reduce the volume to a minimum;
2. To control by burning all gases released from the sludge; and
3. To produce a material which can be disposed of readily by economical means.

10.1 DESCRIPTION OF PROCESS

10.11 Sludge Drying

Sludge cake from the vacuum filter may be dewatered further by heat drying. Moisture is reduced to about 10 per cent, thereby increasing the total solids content of the sludge cake from about 30 to about 90 per cent. Odor-producing substances are reduced to the point where dried sludge may be placed on land surfaces without creating a nuisance.

When activated sludge is heat dried at normal operating temperatures, disease organisms are eliminated, justifying general use of this product as a fertilizer or soil conditioner.

Gases released during the drying process are offensive and should be destroyed or greatly reduced by oxidation at high temperatures before release. The fine ash carried out with the gases is an unwanted addition to the atmosphere. It may be controlled by adding moisture in the stack before release to the atmosphere or by other methods.

10.111 Flash Drying:—This process subjects sludge cake to high temperatures for a short period (Figure 10–1). The cake is first mixed with some dry sludge to reduce its moisture content, break it up, and make it less sticky. The mixture is then put into the drying system where it is moved at a velocity of several thousand feet per minute in a stream of gas having a temperature of about 1,100°F. It passes through this high temperature zone in a few seconds, during which the moisture is reduced to about 10 per cent. In a cyclone separator, the dried sludge is separated from the gases and vapors. The dried sludge has a temperature of about 180°F and none of the fertilizing properties in the original sludge cake has been destroyed. Gases released from the system may be burned to reduce odors. The sludge is now ready for disposal. It may be conveyed by air to a separate furnace for conversion to ash.

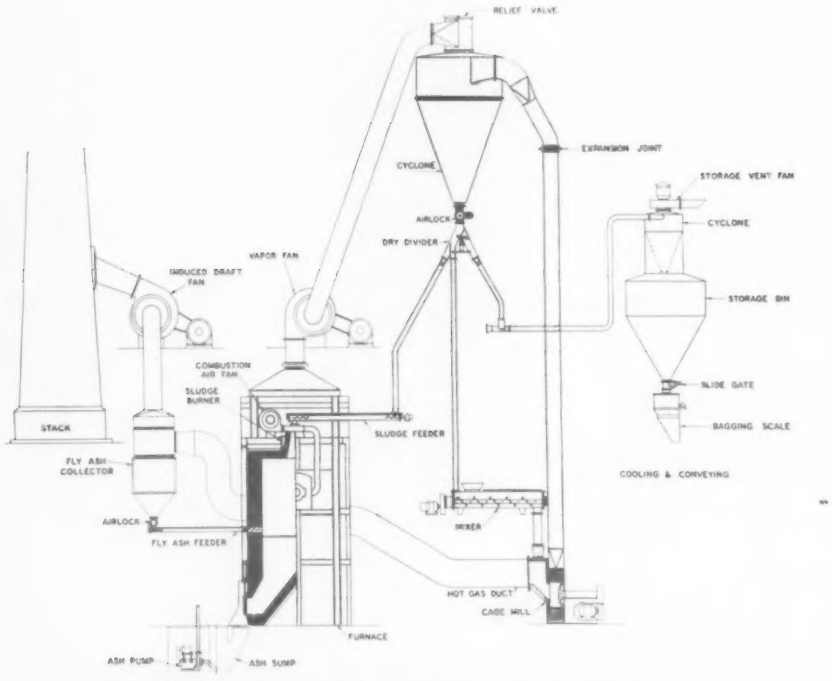


FIGURE 10–1.—Flash drying system with incinerator.

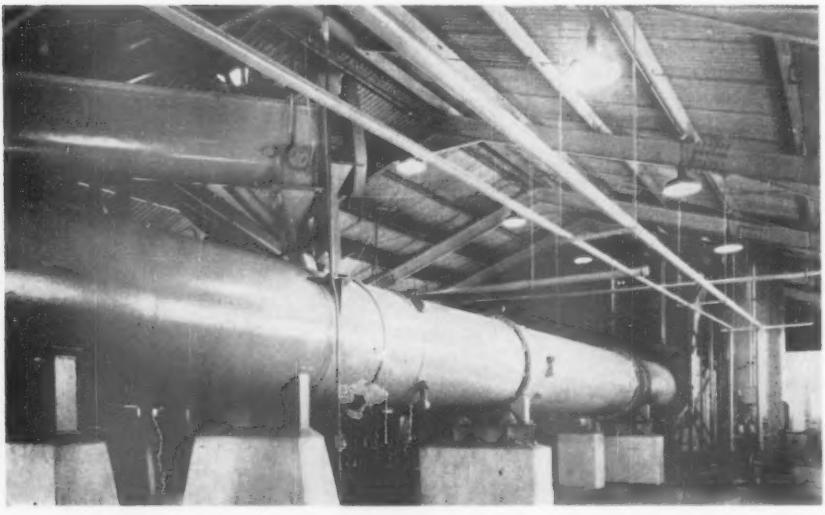


FIGURE 10–2.—Rotary-kiln dryer. Pug mill at upper left feeds sludge to dryer.

10.112 Rotary-Kiln Drying:—This system consists of a rotating cylinder revolving at speeds of 4 to 8 rpm, with heated gases entering at one end with the sludge cake (Figure 10–2). Baffles or flights help break up and mix the drying sludge as it passes from inlet to outlet. A portion of the dried sludge is returned for mixing with the sludge cake, thereby reducing its moisture and breaking it up before it is subjected to drying. The dried sludge is quite granular and may contain clinker-like masses which require grinding before use as a fertilizer or soil conditioner.

10.113 Wet-Sludge Drying:—Wet sludge may be dried by spraying it into a vertical tower through which hot gases are passed downward. The water is evaporated from the atomized particles and passes off with the hot gases as the dried sludge drops to the bottom of the tower. Dust carried with the hot gases is removed by a dust catcher or separator. The dried solids may be used as a fertilizer or burned.

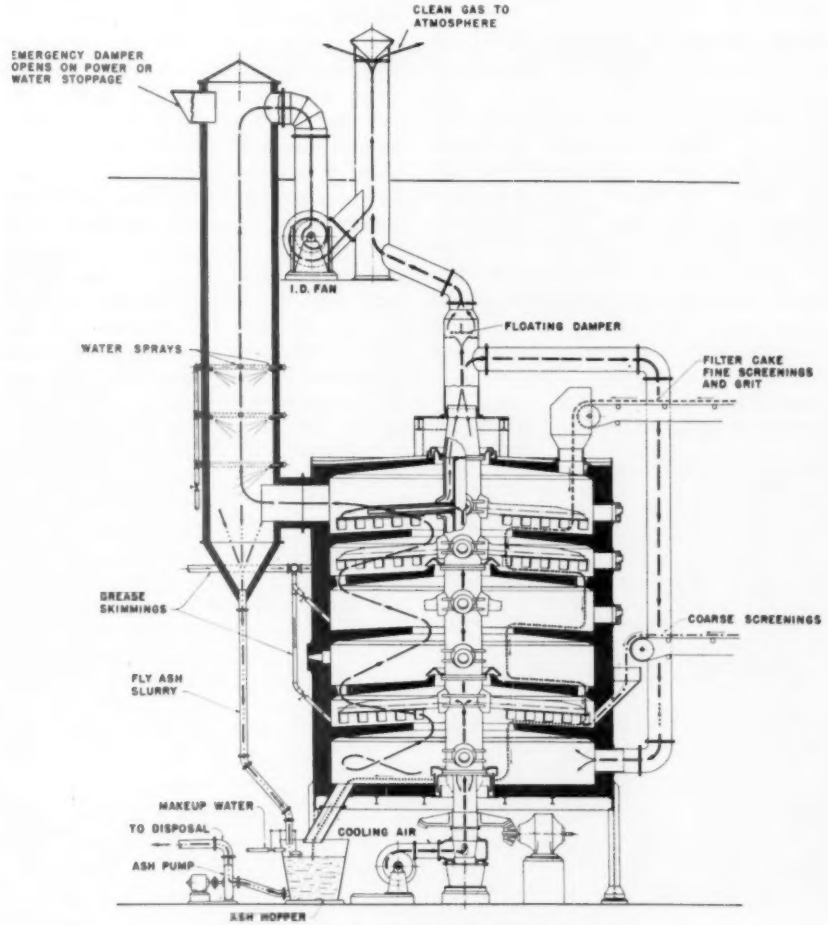


FIGURE 10–3.—Multiple-hearth furnace.

10.12 Incineration

Dewatered or dried sludge is converted to ash by burning at temperatures between 1,250 and 1,600°F. This may be accomplished in either a cyclone or flash-type furnace, installed in connection with a flash dryer, or in a multiple-hearth furnace.

10.121 Flash Type:—The fluffy, dried sludge produced by the flash dryer may be blown into the fire box of this kind of furnace in a manner similar to that used for applying powdered fuel. The heat of combustion is used for operation of the dryer.

10.122 Multiple Hearth:—This unit is a combination dryer and incinerator (Figure 10-3). The furnace consists of a vertical cylinder lined with fire brick or other refractory. A series of four or more hearths are mounted one above the other. The dewatered sludge is fed onto the uppermost hearth where it is partially dried by hot gases from the lower hearths. Rotating plows or mechanically operated rakes move the sludge successively from one hearth to another until dried sufficiently for burning. Temperatures range from about 1,000°F on the top hearth to about 1,600 to 1,800°F on the middle hearth and down to about 600°F on the bottom hearth. The exhaust gases are used to preheat air returned to the top hearth.

10.123 Control of Waste Gases and Fly Ash:—In all types of incinerators, the waste gases from combustion must be heated to about 1,250°F or higher and kept there until they are completely burned to prevent odor nuisance. It is also essential to remove dust, fly ash, and soot. This is usually accomplished by a centrifugal separator or an electrical precipitator.

10.124 Auxiliary Fuel:—Raw primary solids with about 70 per cent volatile content have a heat value of about 8,000 Btu/lb of dry solids. No auxiliary heat is required after combustion has been started, and usually there is an excess of heat from the incineration process. Raw activated sludge often requires auxiliary heat for effective incineration. Digested sludge may or may not require auxiliary heat, depending on the moisture content of the sludge cake and its volatile content. Supplementary heat is required to start operations and sustain them until effective combustion of the solids has been established.

11. SLUDGE DISPOSAL

Sludge is generally spread on land or buried. At a few places, it is discharged to the ocean or other very large bodies of water, but this method is so exceptional that it does not warrant discussion here.

Disposal on or into the land is accomplished in many ways and at all stages of sludge treatment. The principal methods used are:

1. Distribution on the land as a fertilizer or soil conditioner. (All plant operators interested in this method should refer to the Federation Manual of Practice No. 2, *Utilization of Sewage Sludge as Fertilizer.*),
2. Distribution on land as ash,
3. Lagooning,
4. Burial, and
5. Land fill.

11.1 DESCRIPTION OF METHODS

11.11 Fertilizer or Soil Conditioner

The commonest method of disposal for all classes of sludge is by distribution on land surfaces for agricultural purposes. Sludge in the following forms and conditions is distributed by many methods:

1. Sludge from drying beds should not be used on soils where vegetables and fruits would come directly in contact with it. Sludge of this nature may contain significant quantities of disease organisms. Sludge from drying beds may be used for farm crops by plowing or harrowing it into the soil by ordinary land-preparation methods. It may safely be used also for lawns in parks, cemeteries, and other areas where direct personal contact is minimal.

2. Sludge from vacuum filters may be distributed in the same general way as sludge from sand beds, with the same restrictions on its use.

3. Heat-dried activated sludge, as well as heat-dried digested sludge, is safe from a public health standpoint. Frequently, such sludge is bagged or packaged for convenient handling and distribution (Figure 11–1).

4. Liquid sludge, either raw or digested, generally is unsafe for use as a fertilizer or soil conditioner except for farm crops and soil building where opportunity for direct human contact is practically non-existent (Figure 11–2).

11.12 Disposal as Ash

When sludge of any quality is converted to ash by burning at tempera-

FIGURE 11–1.—Bagging dried sludge.

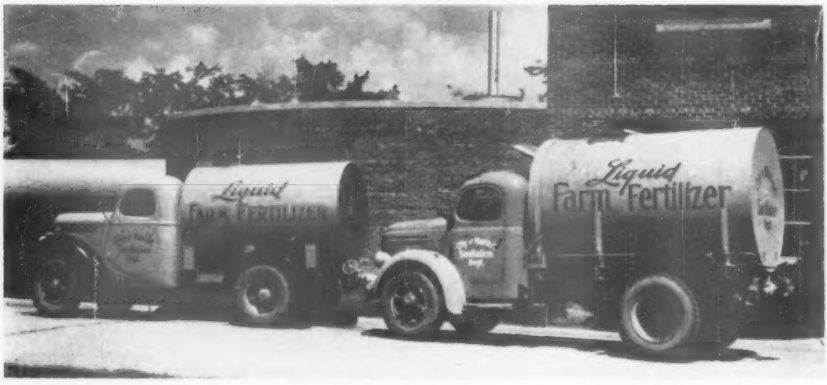


FIGURE 11-2.—Tank trucks for hauling liquid sludge.

tures of 1,400 to 1,600°F, organic material and disease organisms are effectively destroyed.

The ash may be used for fill or merely sluiced to the ground surface nearby. It has no value as a fertilizer and little, if any, value as a soil conditioner.

11.13 Lagooning

Wet sludge, either raw or digested, as well as supernatant, is frequently lagooned either as a temporary or permanent measure. Lagoons may be natural or artificial.

Lagooning of raw undigested sludge or poorly digested sludge as a long-term means of disposal is generally unsatisfactory because of the nuisances produced from odors arising from decomposition.

Well-digested sludge may be lagooned and allowed to dewater naturally by percolation and evaporation. This is followed by removal of the sludge residue by bulldozers or other appropriate methods. Some nuisance may be created and for that reason lagoons should be isolated from residential areas and commercial establishments requiring freedom from odors.

Possible pollution of subsurface water-bearing formations should be carefully considered before lagooning of sludge is undertaken.

11.14 Burial

Burial of sludge is not feasible in most circumstances. Where large well-isolated areas are available, burial may be accomplished by discharging raw sludge into trenches. To control odors, these trenches must be covered with earth as the sludge is placed in them. Raw sludge in small quantities may be disposed of by this method when no other method is available or the sludge contains constituents which render other methods impracticable. Burial should be performed by methods similar to those used for burial of screenings.

11.15 Land Fill

Raw sludge, either wet or dewatered on vacuum filters, should be used for fill only where it is controlled as a sanitary land fill, i.e., the sludge is covered promptly with earth or other suitable materials.

Well-digested sludge, both wet and dewatered, may be used satisfactorily for land fill. The need for covering with earth or other suitable material depends on location and the odor problem anticipated.

DEEDS AND DATA

"That writer does most who gives the reader the most knowledge and takes the least time."

Highlights from the Annual Reports of Aurora, Ill., Beaver Dam, Wis., Las Vegas, Nev., Rochester, Minn., Santa Rosa, Calif., Walla Walla, Wash., and Worcester, Mass.

WILLIARD P. PFEIFER, *Superintendent, Aurora Sanitary District, Aurora, Ill.;* JOHN F. BUDDE, *Chief Plant Operator, Beaver Dam, Wis.;* R. P. SAUER, *Director of Public Works, Las Vegas, Nev.;* W. C. HOGENSON, *Superintendent, Rochester, Minn.;* M. B. MCKINNIE, *Superintendent, Santa Rosa, Calif.;* C. S. ZICKEFOOSE, *Superintendent, Walla Walla, Wash.;* and GEORGE E. MACDOWELL, *Superintendent, Worcester, Mass.*

Garbage Grinders

Results of 19 composite samples from Rochester, Minn., revealed that the BOD of raw sewage in 1959 was 30 per cent greater than in 1958 and the suspended solids increase approached 20 per cent; both increases were computed on a pound basis. This increase coincides with the removal of restrictions on the use of garbage grinders. There was an absence of any evidence that would suggest increases in sewage strength from other sources.

Industrial Wastes

In an earlier report from Beaver Dam it was reported that lime sludge from the new water treatment plant caused damage to the growth on the trickling filter. The current report mentions that the lime waste also interfered with sludge digestion, causing gas production to stop and odors to develop. The lime sludge is now hauled away in a tank truck.

Walla Walla's troubles with *Sphaerotilus*, first reported in DEEDS AND DATA in June 1960, have not decreased. But from studies now completed, the most promising answer to the treatment of canning wastes seems to be the trickling filter.

A portion of the Washington Pollution Control Commission's requirements in the Walla Walla case states that "At the location of the first legal irrigation diversion downstream, the water shall be satisfactory for irrigation purposes and shall be incapable of sustaining slime growth."

Operation

Operating data from seven trickling filter plants appear in Table I.

Oxidation Ponds

The median coliform concentration (MPN) of the effluent from the Santa Rosa oxidation pond was 152 organisms/ml. This is far higher than in other years, and believed to be caused by the low water level that was maintained in the second pond for extraordinary reasons. During May to October, the critical season, MPN levels were held to 62 per ml.

Pond water is a particular favorite of farmers who took 18 mil gal of effluent between June and September. There were several times during the summer when no water reached the stream. This is a little more serious than might be imagined, for the inadequate circulation is believed to have been the cause of conditions which re-

TABLE I.—Operating Results from Seven Trickling Filter Plants

Treatment Plant	Operating Yr Ending	Est. Pop. Served	Sewage Volume				Sewage Temp. (°F)			Sewage Strength (mg/l)				Efficiency of Treatment (%)						Grit Removed (cu ft/mil gal)
			Avg (mgd)	Max Day (mgd)	Min Day (mgd)	Per Cap (gpd)	Avg	Max	Min	Influent		Effluent		Primary Unit		Secondary Unit		Over-all		
										BOD	SS	BOD	SS	BOD	SS	BOD	SS	BOD	SS	
1. Aurora, Ill.	12/59	70,000	10.3	13.5	—	140	61	72	40	96	198	14	41	33	53	78	56	86	78	0.5
2. Beaver Dam, Wis.	12/59	12,000	1.8	3.4	0.9	153	58	70	46	196	297	28	28	35	66	78	70	86	90	—
3. Las Vegas, Nev.[e]	6/60	24,624[f]	10.0	—	—	—	76	88	63	167	175	18	15	—	—	—	—	89	91	4.6
4. Rochester, Minn.	12/59	29,885[f]	3.8	5.4	2.5	—	—	74	52	325	279	68	53	—[g]	—[g]	79	80	79	80	—
5. Santa Rosa, Calif.	6/60	21,000[f]	4.9	8.2	3.7	—	—	—	—	257	233	9	81	40	56	72[i]	39[i]	96[i]	65[i]	0.6
6. Walla Walla, Wash.	4/60	26,000	6.1	12.0	4.0	234	—	—	—	128	100	15	31	17	36	86	52	88	69	—
7. Worcester, Mass.	12/59	203,486[f]	29.7	62.0	13.2	—	—	—	—	161	161	28	38	42	65	67	50	83	76	—

Treatment Plant	Primary Sedimentation				Trickling Filters			Disinfection	
	Surface Overflow Rate (gpd/sq ft)	Raw Sludge			Hydraulic Loading (gpd/sq ft)	BOD Loading (lb/day/1,000 cu ft)	Recirculation (%)	Cl_2 Dosage (mg/l)	Effluent Quality (MPN/ml)
		Volume (cu ft/mil gal of sewage)	Dry Solids (lb/mil gal of sewage)	Solids Conc. (%)					
1. Aurora, Ill.	—	287	786	5.2	63	5.6	0	—	—
2. Beaver Dam, Wis.	848	454	1,340	4.7	80	—	—	—	—
3. Las Vegas, Nev.[e]	—	505	1,520	1.8	—	—	200–300	2.5	—
4. Rochester, Minn.	—[g]	—[g]	—[g]	—[g]	398	86	109	—	—
5. Santa Rosa, Calif.	1,180	370	1,340	5.8	632	75	160	0	152[h]
6. Walla Walla, Wash.	—	289	705	3.9	—[m]	—	—	2.3	—
7. Worcester, Mass.	—	—	—	—	72	—	0	—	—

TABLE I.—*Continued*

Treatment Plant	Sludge Digestion					Supernatant		Gas				Sludge Filtration				Operating Cost ($/mil gal)
	VS Loading (lb/day/1,000 cu ft)	VS Red. (%)	Temp. (°F)	Vol. Acids (mg/l)	Alk. (mg/l)	pH	Volume (cu ft/mil gal of sewage)	Solids Conc. (mg/l)	Produced (cu ft/day/cap)	Produced (cu ft/lb VS fed)	Used (%)	Heat Value (Btu/cu ft)	CO_2 (%)	Dry Yield (psf/hr)	$FeCl_3$ Fed (%)	CaO Fed (%)	TS in Cake (%)	
1. Aurora, Ill.	92[a]	—	89–93[b]	—	—	—	—	3,100	0.6	7.1	99	571	33	—[c]	—	—	—	28.64
2. Beaver Dam, Wis.	16	76	82–85[b]	—	—	7.3	324	—	—	—	—	—	—	—[d]	—	—	—	26.57
3. Las Vegas, Nev.[e]	55[a]	68	85	—	—	7.3	—	—	—	8.8[b]	—	—	—	—[c]	—	—	—	29.07
4. Rochester, Minn.	42[a]	68	90–95[b]	—	—	—	279	—	—	10.9	69	33	—	—[c]	—	—	—	37.85
5. Santa Rosa, Calif.	73[a]	68	—[f]	—	—	—	—	—	1.3	11.0	—	—	—	—[g]	—	—	—	18.81
6. Walla Walla, Wash.	—[a]	68	—	—	—	—	—	—	—	—	—	—	—	—[g]	—	—	—	11.15
7. Worcester, Mass.																		

[a] On primary unit. [b] Two-stage digestion. [c] Sludge drying bed used. [d] Wet sludge mostly trucked to farms; some to beds. [e] Plant No. 1. [f] 1950 population. [g] No primary sedimentation; fine screening only. [h] For primary unit only. [i] Does not include subsequent results of oxidation pond treatment. [j] Includes subsequent removal in oxidation ponds. [k] Oxidation pond effluent. [l] 64, 96, 63 in top, middle, and bottom of primary unit. [m] Two-stage filtration; first stage is high rate; second stage is low rate. [n] Drying beds and lagoon used. [o] Imhoff tanks used.

sulted in some odor nuisance. As soon as pond overflow was reestablished, the odor and scum disappeared.

In addition to farmers, birds and bird watchers have taken a liking to the ponds. The watchers needed three pages to list the variety observed.

Screening

An unusual item in connection with the Rochester plant is that raw sewage is pumped to the trickling filters immediately after fine screening, skipping primary sedimentation. Solids failing to pass the 8-mesh screen approximate 16 per cent of all solids removed in the plant. The BOD removed by the screen is believed to be small.

Sewers

Santa Rosa reports that rodding costs for the first year its power machine was in operation averaged 3.8¢/ft. A two-man crew rodded 39.2 miles of what was mostly 6-in. sewer pipe. Pipe capacities seem to have been increased noticeably. The older lines all harbored quantities of rocks and "just plain junk." At times more than 5 gal of debris was taken from 300 ft of 6-in. sewer. An old set of wood sewer rods, 10 or 15 years on the loose, was rescued from oblivion.

TIPS AND QUIPS

Hear! Hear!

The bright Miss Dimmers of the Water and Sewage Works Manufacturers Association sent us a clipping of a recent UPI dispatch from Skegness, England, which is worth repeating.

It seems the local health committee had a beef about the tourist literature slighting one of the town's most important assets. To right the wrong, the next edition of the official guidebook will contain a "suitable" picture of the sewage treatment plant.

Swimmers' Itch

The *Cause and Control of Swimmers' Itch in Michigan* is the title of a new bulletin of the Michigan Water Resources Commission. It discusses the life history and geographical distribution of the parasite which is the cause of the itch. The bulletin is available from the Commission offices at Station B, 300 E. Michigan St., Lansing 13, Mich.

Oil Pollution of Coastal Waters *

Two years ago the New England Interstate Water Pollution Control Commission warned through the press that oil spills and discharges by coastal and naval vessels were causing serious damage to our ocean waters and beaches.

The most recent report in this regard involves the presence of an oil slick in the Chatham-Orleans area of Cape Cod. The oil covered a wide strip of beach and killed marine life. The Coast Guard reported that the slick could be detected over a 7-mile area and was unquestionably due to the discharge of oil from the bilges of a tanker somewhere offshore. It is reportedly common practice to pump out the bilges which contain excess oil not emptied in port.

Oil pollution from such sources is an international problem and discussions in Geneva in 1954 led to a Convention on Pollution of the Seas by Oil. The Convention has since been ratified by 16 nations, but not the United States. It sets up no-dumping zones of varying width off countries having pollution problems. Other provisions provide that ships must carry logs into which must be entered every instance of an oily-water discharge, that special provision be made on ships to prevent escape of fuel oil into bilges, and that the signing governments guarantee provision of port facilities for handling of oily wastes.

President Eisenhower sent notice of the Convention to the Senate last February for consideration, but to date no action toward ratification has been taken.

How 'Strikes' Began

An article in the *Paper Makers Journal* says the first recorded use of the word "strike" dates from the year 1200. It means "to make one's way," as in "strike out for home." In 1707 the *London Gazette* reported a battle, saying, "The enemy struck their tents and formed in line."

The next step came when an event at Bath involving a masters' guild was described as follows: "This day the whole body of chairmen . . . struck their poles and proceeded in a mutinous way to Guildhall, respecting the granting of their licenses."

The *Annual Register of Britain* reported in 1768 that "this day (May 9) the hatters struck and refused to work till their wages are raised." Less than 50 years later the word was first heard in America when the Society of Cordwainers of New York—the shoemakers' union—ordered a "general strike" of its members.

* From the Newsletter of the New England Interstate Water Pollution Control Commission, June 1960.

Federation Affairs

RAY E. LAWRENCE THE 1961 PRESIDENT

Ray E. Lawrence, partner in the firm of Black and Veatch, was elected President of the Federation at the Election Committee meeting on Oct. 2, 1960.

Mr. Lawrence began his career with Black and Veatch immediately after graduation from the University of Kansas in 1925. He was appointed engineer for the Kansas State Board of Health and a member of the Civil Engineering staff of the University of Kansas in 1926. During the period of 1926–33 he was engaged in sanitary engineering and served one year as Acting Chief Engineer for the Kansas State Board of Health.

In 1933 he left the University to serve as Engineer Examiner and later as State Director for Kansas under the U. S. Public Works Administration. In 1937 he returned to Black and Veatch as a Principal Engineer and supervised a number of water supply and sewerage projects for cities in the Midwest.

From 1941 to 1946 Mr. Lawrence worked with the war effort, first as a civilian and later as an officer.

For the two-year period of 1944–45 he served overseas with the Chief Engineer, European Theater, and achieved the rank of Colonel. His duties included the logistical planning of utility construction for the Continental invasion and the restoration of utility services supplying the military and civilian populations in France and Germany. For this service, Mr. Lawrence was awarded the Legion of Merit.

Since his return to Black and Veatch in 1946, Mr. Lawrence has been responsible for the planning and prosecution of major engineering projects.

Mr. Lawrence is a registered professional engineer in the states of Kansas, Missouri, Nebraska, and New Mexico. He has been active in a number of technical societies and has served as a Director of the Federation. Other current activities include: membership on the Executive Committee, Sanitary Engineering Division, American Society of Civil Engineers; membership on the Board of Trustees, American Sanitary Engineering Inter-Society Board; and the Committee on Sanitary Engineering and Environment of the National Research Council Advisory Committee on Medical Sciences.

HARRY E. SCHLENZ ELECTED VICE-PRESIDENT

Harry E. Schlenz, President of the Pacific Flush Tank Company, Chicago, Ill., was elected Vice-President of the Federation at the Election Committee meeting on Oct. 2, 1960.

For many years a leader in the field of water pollution control, Mr. Schlenz is well-known to Federation members. He has served the Federation in many capacities and currently serves on the Finance, Public Relations, and Convention Management Committees. Until his election to the vice-presidency, he served on the Board of Control as a representative of the Water and Sewage Works Manufacturers Association. He was president of the latter organization in 1951.

Born in Denver, Colo., Mr. Schlenz was graduated from the University of Illinois in 1927 with a B.S. in Sanitary Engineering. In 1929 he received an M.S. in Civil Engineering and in 1933 was awarded the professional degree of Civil Engineer. He has been with the Pacific Flush Tank Company since 1930.

Mr. Schlenz, a long-time Federation member, is also a member of the American Water Works Association, American Society of Civil Engineers, Illinois Society of Engineers, American Public Works Association, Engineers' Club of New York, and the Army and Navy Club of Chicago.

Mr. Schlenz served on the Steering Committee of President Eisenhower's National Conference on Water Pollution which was held in Washington a few days ago.

PHILADELPHIA REPORT

Something happened at Philadelphia during the week of October 2. We don't know exactly what, but just about every Federation convention record was smashed. Total registration soared to 1,720—1,395 men and 325 ladies.

Going back to the beginning, preregistrations began arriving at the Federation office in record-breaking numbers. Then the convention housing bureau began reporting record-breaking numbers of room reservations. From these reports it seemed certain that a record was in the offing, but not even the most optimistic came close to guessing what the total attendance would be. The 1,720 in Philadelphia exceeded the previous high (Boston in 1957) by 357.

Fortunately for all, Sam Baxter had his Local Arrangements Committee geared for the big turnout. Shuttle-bus service between the technical sessions at Convention Hall and the social events at the Sheraton was extraordinarily successful, and John Cappio deserves a lot of thanks for working out the schedule.

Mr. and Mrs. Stanley Kappe and the Local Host Committee, resplendent in Colonial dress, must have invented hospitality, judging from the comments we heard, and everyone from the Pennsylvania Water Pollution Con-

President Hollis, Secretary Flemming, and President-Elect Lawrence

trol Association took it upon himself to make visitors welcome.

For making an outstanding convention, the Federation will remember the work of: George Symons and the Program Committee; Harry Schlenz and the Convention Management Committee; Mrs. Samuel Baxter and the Ladies' Entertainment Committee; Morris Hicks and the Entertainment Committee; Barney Palmer, Tom Mullineaux, and the registration teams; George Elias and the Finance Committee; Ralph Hoot and the Inspection Trip Committee; Joe Gilbert and the Hotel and Convention Hall Arrangements Committee; Grant Howell and the Publicity Committee; and Sam Zack and Al Estrada of the Local Arrangements Committee.

Technical Program

The technical program was the largest ever—13 sessions. The attendance at these sessions and the luncheons might be classified as heavy and heavier or full and overflow. Speakers were effective and the discussions were stimulating.

Spokesmen representing two large segments of the nation were the luncheon speakers. First, there was the Secretary of Health, Education and Welfare, Arthur S. Flemming, who discussed in some detail and with great vigor the Eisenhower administration's views and recommendations on water pollution control policy and legislation.

The following day, Robert G. Dun-

Sun Oil President Robert G. Dunlop

lop, President of the Sun Oil Co., presented a polished, documented summary of the petroleum industry's actions in pollution control. Drawing an analogy between petroleum conservation and pollution abatement, Mr. Dunlop detailed his own company's position to a highly attentive audience.

The innovation this year designating Wednesday as Industry Day and extending convention invitations to many not now affiliated with the Federation was successful.

Most of the papers presented at the meeting will appear in the JOURNAL during 1961.

Entertainment Events

An "Album of Memorable Music" was the Monday evening high point. Headlining the billing were singer Jack Russell, well remembered from his four and a half years with the Sid Caesar–Imogene Coca "Your Show of Shows" and Bonnie Murray, who won everyone's praise last year in Dallas. The show was an outstanding success.

Wednesday evening's Awards Banquet in the Sheraton Ballroom was attended by more than 850 members and guests. Following the awards presentation, there was dancing.

Inspection Trips

Wonderful weather heightened interest in the inspection trips to the Atlantic Refining Co., Philadelphia's Northeast plant, and the Whitemarsh Township facilities. Moreover, the trips were a welcome change of pace in the technical program.

Manufacturer's Exhibit

The Water and Sewage Works Manufacturers Association arranged the largest equipment exhibition ever displayed at a Federation convention. Fifty-six exhibitors occupied over 100 booths in spacious Convention Hall.

It appeared that the exhibit area was better located and far busier than in previous years.

Publicity and News Coverage

Preparation for publicity and news coverage began in advance of the convention. Over 120 news releases were written to include every person on the program. These were mailed to the participant's local papers, his employer, and journals which he suggested. News releases on the convention itself were mailed to trade publications, Philadelphia area news outlets, and wire services.

A new accommodation was the "package news kit" for trade journals. Each kit contained all releases and abstracts, as well as stories and pictures of Federation officers and awardees. These were available in the convention news room.

The Convention Publicity Committee and the Pennsylvania Association did a remarkable job in securing experts to conduct the Federation's first full-time coordinated publicity program. Because of their work, the following individuals deserve special praise: Grant Howell, Joe McGinty, Andy Staursky, Fritz Foote, and Marian Castaldi, all of U. S. Steel; Ray Harris, convention news room chief, from the Philadelphia Water Department; William Getty of Sun Oil; John Murdoch of the Pennsylvania Department of Health; Tom McNeil of Eimco; Clayton Billings of *Public Works;* and Dean Kearsh and Gene Oliva of J. Walter Thompson.

Secretary Flemming appeared on television news broadcasts six times, *Business Week* ran a story, and the newspapers featured several excellent stories throughout the convention.

For the first time news releases and abstracts were distributed during the convention. The selection of two strategic places allowed everyone to obtain these items.

The releases prepared on the participants resulted in the broadest publicity of any convention. In the case of the package news kits, the trade

journal representatives were especially grateful. Wide praise for the smooth operation of the news room established this as a most successful endeavor. The Federation thanks everyone who helped to make it possible.

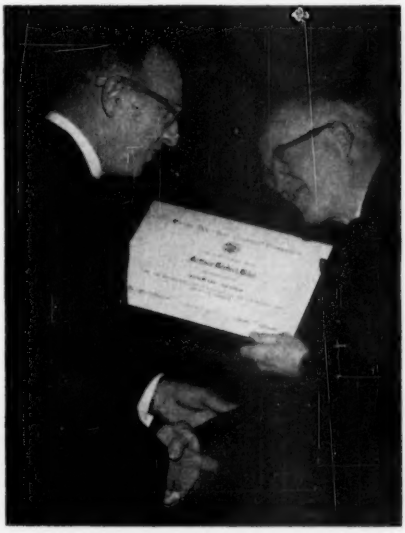
1960 Awards

Honors and awards conferred by the Board of Control were presented by President Hollis in an impressive ceremony at the Awards Banquet on Wednesday.

Past-President Hatfield, on right, receives Past-President's Certificate from President Hollis.

Presented with the Past-Presidents' Certificate was William D. Hatfield, Consultant, Decatur, Ill., in appreciation of his outstanding service as President during 1959.

Honorary Membership was bestowed on Arthur H. Niles, Consultant, Boca Raton, Fla., and Federation Treasurer. Mr. Niles served as Federation President, 1949–50, and is a long-time contributor to technical publications as well as a highly productive member of many Federation committees.



New Honorary Member Arthur H. Niles, on right, receives certificate from President Hollis.

Honorary Membership also was given to the late Renville Stevens Rankin, who closed a distinguished 47-year career on June 6, 1960. Mr. Rankin was a leader in the develop-

Emerson Medal winner Frederick H. Waring

Stephen A. Klein receives Harrison Prescott Eddy Medal from President Hollis.

ment of new and improved equipment for water pollution control.

The Charles Alvin Emerson Medal was received by Frederick H. Waring in recognition of his dedicated and illustrious service to the Water Pollution Control Federation, particularly toward fulfillment of the Federation's objectives. Mr. Waring serves as Chief Sanitary Engineer, Ohio State Department of Health.

The Harrison Prescott Eddy Medal went to P. H. McGauhey and Stephen A. Klein of the University of California for their paper, "Removal of ABS by Sewage Treatment," as published in the August 1959 issue of SEWAGE AND INDUSTRIAL WASTES.

Gascoigne Medal winner C. D. Parker

President Hollis congratulating Industrial Wastes Medal winners Claude de Courval and T. W. Beak.

Theirs was an outstanding research contribution furthering the understanding of detergent removal from wastewater.

The recipients of the George Bradley Gascoigne Medal were Cecil D. Parker, Harold L. Jones, and Neil C. Greene, all of the Melbourne and Metropolitan Board of Works Research Laboratory, Melbourne, Australia. This award was in recognition of the excellence and importance of their paper, "Performance of Large Sewage Lagoons at Melbourne, Australia," as

published in the February 1959 issue of SEWAGE AND INDUSTRIAL WASTES.

The Industrial Wastes Medal was awarded to T. W. Beak, Claude de Courval, and Norman E. Cooke, for their authorship of "Pollution Monitoring and Prevention by Use of Bivariate Control Charts," as published in the December 1959 issue of SEWAGE AND INDUSTRIAL WASTES. This paper presented an important, new application of mathematical statistics to the findings of biological investigations for the evaluation of the pollutional effects of an industrial waste. Canadians all, Mr. Beak is a consulting biologist from Kingston, Ont.; Mr. de Courval is principal chemical engineer and Dr. Cooke is mathematical statistician, Canadian Industries Limited, Montreal, Que.

Nominations for the 1960 Arthur Sidney Bedell Awards, for service to Member Associations of the Federation, were confirmed by the Board as follows: C. L. Gray (Alabama); Art F. Vondrick (Arizona); Sydney Preen (California); Antoine V. Delaporte (Canada); Robert W. Frazier (Central States); N. J. Tatman (England–IPHE); M. E. Dawkins (Florida); Franz Schmitz-Lenders (Germany); B. A. Poole (Indiana); James F. Aiken, Jr. (Kansas); Jack E. Cooper (Michigan); J. E. Johnston (Mississippi); Jack K. Smith (Missouri); Earl R. Howard (New England); Andrew Palmer (New Jersey); C. E. Irving (New York); E. F. Wittmer (Ohio); Harry W. McElhaney (Pennsylvania); André Kropf (Switzerland); and Lynn M. Thatcher (Utah).

Nominations for the 1960 William D. Hatfield Awards, for outstanding treatment works operation, were confirmed by the Board as follows: James L. Slovensky (Alabama); E. O'Neil Dye (Arizona); William R. Teague (California); William Hardy (Canada); D. A. Whitlock (Central States); George T. Lohmeyer (Florida); W. W. Mathews (Indiana); V. W. Pickering (Kansas); Lloyd B. Tompkins (Michigan); Sidney C. Smith (Missouri); Steven A. Stankey (New England); Edward F. Lawler (New Jersey); F. J. Cramer (New York); T. C. Schaetzle (Ohio); Paul Cygan (Pennsylvania); and Emil Meyer (Utah).

Membership

The Secretary reported that the combined Honorary, Active, and Corporate Membership of the Associations constituting the Federation was 8,376 on Sept. 30, 1960, just slightly under last year's all-time record of 8,559. Eighteen associations showed gains; 24 showed losses; and 2 showed no change.

The number of Associate Members on September 30 was 85; a year ago it was 76.

The Indiana Association won the membership prize for the largest numerical increase by gaining 50 new members. The winner for the greatest percentage increase was the New Zealand Association, registering a 21-per cent increase. Close behind was South Carolina with a 16-per cent gain.

During the year, separate Associations for the Dakotas were established. Formerly, these two groups had been one.

Atlantic City in 1965

The Meeting Place Committee recommended, and the Board approved, Atlantic City, N. J., as the 1965 meeting place. The convention will be held Oct. 10–14, 1965, using the facilities of Convention Hall and the Traymore Hotel. Previously approved and announced dates and locations are:

1961, Milwaukee, Wis., Schroeder Hotel, Oct. 9–12.
1962, Toronto, Canada, Royal York Hotel, Oct. 8–11.
1963, Seattle, Wash., Olympic Hotel, Oct. 6–10.

1964, Bal Harbour, Fla., Americana Hotel, Sept. 27–Oct. 2.

In accordance with the Board's instructions, the Committee concerned itself with the following invitations in determining the 1965 selection: Georgia (Atlanta), Kentucky-Tennessee (Memphis), Missouri (St. Louis or Kansas City), New Jersey (Atlantic City), New York (New York), Pennsylvania (Pittsburgh), Rocky Mountain (Denver).

Bedell and Hatfield Award Nominations

The accompanying schedule of Bedell and Hatfield Award nominations was approved by the Federation Board of Control on Oct. 2, 1960. The award schedule is included for the current three-year period. Those Member Associations with changes in membership which place them in a different category for award eligibility are included in the future schedule.

Directors-at-Large

The new director-at-large is Andrew J. Wahl, Director of Public Works, Boise, Idaho. The new Federation directors elected by the Board of Governors of the Water and Sewage Works Manufacturers Association are Everett M. Jones, Assistant to the Vice-President, Rockwell Manufacturing Co., Pittsburgh, Pa., and Alan F. Nagle, Keasbey and Mattison Co., Ambler, Pa.

Bedell and Hatfield Award Schedule

(Date of Award is year submitted to Board of Control)

Member Association	Members		Nominations Per 3 Years	Future Schedule*		
	9-30-59	9-30-60		1961	1962	1963
Alabama	50	46	1	—	—	√
Alaska	—	15	1	—	—	√†
Arizona	48	50	1	—	—	√
Arkansas	42	36	1	√	—	—
California	636	605	3	√	√	√
Canada	631	644	3	√	√	√
Central States	634	617	3	√	√	√
Federal	93	92	1	√	—	—
Florida	451	430	2	√	—	√
Georgia	101	82	1	—	√	—
Germany	44	48	1	—	—	√
Indiana	231	281	2	√	—	√
Iowa	143	136	1	√	—	—
IPHE (England)	23	21	1	—	—	√
ISP (England)	127	113	1	√	—	—
Israel	0	0	1	—	—	√†
Kansas	160	135	1	—	—	√
Kentucky-Tennessee	200	191	1	√	—	—
Louisiana	18	16	1	√†	—	—
Maryland-Delaware	81	87	1	—	√	—
Michigan	534	503	3	√	√	√
Mississippi	100	89	1	—	—	√
Missouri	73	72	1	—	—	√
Montana	39	38	1	—	√	—
Nebraska	85	66	1	√	—	—
New England	411	413	2	—	√	√
New Jersey	338	330	2	—	√	√
New York	667	661	3	√	√	√
New Zealand	33	40	1	—	—	√†
North Carolina	162	168	1	√	—	—
North Dakota	14	19	1	—	√†	—
Ohio	439	441	2	—	√	√
Oklahoma	47	48	1	—	√	—
Pacific Northwest	353	355	2	√	—	√
Pennsylvania	501	505	3	√	√	√
Puerto Rico	96	78	1	—	√	—
Rocky Mountain	144	131	1	—	√	—
South Carolina	50	58	1	√	—	—
South Dakota	38	43	1	—	√	—
Sweden	120	125	1	√	—	—
Switzerland	17	17	1	—	—	√†
Texas	279	238	2	√	√	—
Utah	52	52	1	—	—	√
Virginia	166	164	1	—	√	—
West Virginia	88	91	1	—	√	—
Totals	8,559	8,376	64	20	20	24

* Schedules for 1962 and 1963 based on membership as of Sept. 30, 1960.
† Year eligible to petition for nominations.

BOARD OF CONTROL ACTS

This year's paramount accomplishment was the "policy statement" printed in the November Journal. Long hours of thoughtful deliberation went into this document, both by the drafting committee and the full Board. That agreement on so many points could be obtained in such a relatively short time bespeaks the dedication to duty which characterizes your Board of Control.

The emergence of the Federation as a respected spokesman on matters of water pollution carries with it new responsibilities as evidenced by requests from other interested organizations for Federation opinion. And in passing, it would be fair to say that the tenor of the Board meetings was one of articulating the national importance of water pollution control.

Guidance, committee recommendations, and authorizations on many other topics, of course, occupied much of the Board's time during its Sunday and Thursday sessions.

Alaska, the 49th state, now is the area served by the 45th Member Association. This new organization, the Alaska Water Management Association with 15 members already in the fold, was enthusiastically received into the Federation.

The Nuclear Wastes Committee, under the chairmanship of Dr. James M. Smith, Jr., reported that his group would welcome the opportunity to be of direct service to Member Associations through participation in their meeting programs.

A report from Dr. Gail P. Edwards, chairman of the Standard Methods Committee, announced the availability of the 11th Edition of *Standard Methods for the Examination of Water and Wastewater*.

Chairman W. A. Hasfurther presented the complete and detailed report of the Personnel Advancement Committee which will appear in an early issue of the Journal. Three recommendations by the Committee were approved by the Board:

1. A model plan for voluntary certification was approved and its use in the promotion of uniformity in certification was authorized.
2. Mandatory certification was endorsed as an ultimate goal.
3. Staff assistance was authorized to help the Committee in furtherance of efforts in the areas of certification and training.

Favorable discussion in support of a Federation safety award resulted in referral of the idea to the Executive Committee.

Admitted into membership of the Quarter Century Operators Club were: Louis J. Fontenelli, Garwood, N. J.; C. Austin Habermehl, Farmington, Mich.; William R. Lafferty, Lakeland, N. J.; Gordon J. Weist, Collegeville, Pa.; Williard P. Pfeifer, Aurora, Ill.; Samuel Cenicola, South Hackensack, N. J.; W. W. Watmough, Hamilton, Ont.; and T. R. Komline, Peapack, N. J.

Beyond considering the immediate task of handling the Alaska petition, the Organization Committee recommended that: (*a*) an Association with fewer than 15 members be admitted to membership in the Federation, with representation on the Board of Control and participation in the membership contest and Federation awards activities delayed until membership reaches 15; and (*b*) that foreign groups be permitted to affiliate with the Fed-

eration after their organization passes a resolution expressing this intent, with members paying Federation dues receiving Federation membership privileges. Both recommendations were approved.

Finance Committee Chairman William J. Orchard presented the Committee's proposed 1961 budget which totaled $182,550, with $5,000 earmarked for transfer to surplus and $13,755 for public relations and operator advancement. The unaudited net worth of the Federation as of Sept. 30, 1960 was $87,086.

Based on this year's success, the Industrial Wastes Committee endorsed the idea of having the industrial wastes committees of other organizations cosponsor the Industry Day program. This year the Water Pollution Abatement Committee of the Manufacturing Chemists' Association was a co-sponsor.

The possibility of developing personal insignia for the Federation was referred to the Public Relations Committee for study.

The Board authorized printing of a slightly revised edition of the now-out-of-print *Uniform System of Accounts for Sewer Utilities.*

Resolutions commending the Pennsylvania Water Pollution Control Association and the city of Philadelphia for their extra-ordinary efforts in making the 1960 convention the Federation's greatest were among the many items of business acted upon by the Board.

PROGRAMMING THE FEDERATION MEETING*

Many Federation members and others have evidenced a desire to know how papers are selected for the annual meeting. This is an explanation of how the Publications and Program Committee operates to fulfill its responsibilities for selection and scheduling of the annual Federation meeting program. Details of publication are also included.

Committee Makeup

The committee consists of a chairman, whose term of office is constitutionally limited to five years, at least four other members including the Executive Secretary of the Federation, plus the Federation President and Vice-President as ex-officio members. During the past five years, the growth of the Federation and the program has necessitated an increase in committee members to 19.

The makeup of the committee is not static, although the vice-chairman and several other members usually serve as long as the chairman does. Geographic distribution of committee members is maintained. Other members are changed each year. In this latter group are persons who have assigned to them the responsibilities for certain recurring sessions. For example, each year a different man is appointed to handle these sessions: Operators Forum, Research Symposium, Maintenance Panels, and Laboratory Scientists Breakfast. (Another committee handles the inspection trip). Also each year, one man is appointed from the area of the annual meeting three years hence. Three years later that man handles liaison with the local arrangements committee for "his" area's meeting. In addition to these "rotating" memberships there are three or four members of the Industrial Wastes Committee or members suggested by that committee or its chairman, and usually at least one of these men is changed every year.

Advance Planning

At the annual meeting of the Federation, the full committee meets for an advance planning session. The work of the committee session follows these steps:

1. A tentative time schedule is blocked out for the next year's meeting, and the number of sessions determined.
2. The theme of each session is then set and entered on a diagram.
3. Individual members of the committee are then assigned responsibility for obtaining the necessary papers to fill particular sessions. These assignments are appropriately selected, i.e. Industrial Wastes Committee members are assigned the industrial wastes, sessions.
4. Ideas as to speakers or topics for different sessions are suggested by all committee members to the individuals responsible for each particular session.
5. A final date for closing the program selections is set. This date is generally May 1 of the following year and is selected in order to meet the production requirements of the "advance flyer" which is mailed out in July.

Committee Work

About November 1 (or earlier) the individual committee members begin their work of searching for papers to fit the theme of the session for which

* Prepared by George E. Symons, Chairman of the Publications and Program Committee.

they are responsible. By letters, calls, and personal contact they seek to learn from Federation members (and from other committee members) where appropriate papers might be obtained.

In late January of the next year the Publications and Program Committee holds another meeting. At that time the individual committee members report on the status of their efforts, and the program schedule chart is filled in as of that date. By that time, about one-half of the papers have been selected or are under consideration.

By March 15, about three-fourths of the papers will have been selected. Competition for papers for the Research Symposium is open until April 1. Researchers who wish to appear on the program should submit a brief abstract of the paper before that date. Between April 1 and April 15, final selection of the research papers is made.

By May 1, all of the selected papers (titles and authors) are in the chairman's hands for transmission to the Executive Secretary, and the selected program participants are notified.

In early June, each programmer receives a letter from the chairman requesting information for the directory and a list of projection equipment required.

In August, each programmer receives another letter from the chairman, setting forth rules for presentation, style to follow, other mechanical requirements, and a request that copies of the manuscript be sent to the Federation office.

In September, the committee for the next year is recommended to the incoming President and plans are made for the October committee meeting.

How to Get on the Program

During the period after the October meeting of one year and until about April 1 of the next year, individual members of the Federation should make suggestions for the coming annual program. These suggestions may include the offer of a paper of their own or the names of other possible authors.

These suggestions should be made in letters addressed to the Chairman of the Publications and Program Committee or to the Executive Secretary of the Federation. All such letters will be routed to the proper committee member for his consideration and reply.

The committee invites your suggestions and offers of papers.

Publication of Papers

All papers given at the Federation meeting become the publication property of the Journal of the Water Pollution Control Federation. The Journal depends heavily on these papers throughout the year for much of its outstanding material. Not all meeting papers are published in the Journal, however. These papers offer the material from which to choose for publication but final selection of papers to be published is determined by the editor.

News and Notes

Of Persons and Activities in the Wastewater Field

The news of the death of **W. T. Lockett** last February, long the Chief Chemist of the Mogden Purification Works in Middlesex, England, was only recently received. He was made an Honorary Member of the Federation in 1954.

Bernal H. Swab has joined **Camp, Dresser & McKee** of Boston. He was Chairman of the committee responsible for the recently published joint Federation and ASCE Manual, "Design and Construction of Sanitary and Storm Sewers."

Fred G. Nelson has recently joined **Koebig and Koebig,** Los Angeles, as Assistant to the President. He retired from **Dorr-Oliver Inc.** in July after 32 years of service.

H. S. Smith has withdrawn as a partner in **Stanley Engineering Company,** Muscatine, Iowa, and Chicago, to do graduate work and research at the State University of Iowa. He represents the Iowa Water Pollution Control Association on the Federation Board of Directors.

Franklin V. Long, President of **Vapor Recovery Systems Company,** Compton, California, died recently.

Among the Top Ten Public Works Men-of-the-Year selected by the American Public Works Association and announced by President **Frederick W. Crane** are **Samuel S. Baxter,** Commissioner and Chief Engineer of the Philadelphia Water Department; **David L. Erickson,** Director of the Department of Public Works and Utilities, Lincoln, Nebraska; and **Lloyd D. Knapp,** Commissioner, Department of Public Works, Milwaukee, Wisconsin.

Harold B. Gotaas, Dean of Northwestern University's Technological Institute, has been named to the Engineering Sciences Committee of the National Science Foundation.

David I. Jenkins is now employed at the Richmond Field Station of the University of California.

Edmund B. Besselievre has resigned from **Kaighin & Hughes, Inc.,** Toledo, Ohio, and has moved to Dallas, Texas, where he will be in consulting practice for industry.

Henry W. Buck, of Hartford, Conn., was recently elected to the post of Director for ASCE, representing part of New England and some sections of Canada.

John R. Snell, President, has announced that the firm name of Michigan Associates has been changed to John R. Snell Engineers Inc. **William G. Turney** and **William P. Richards** are members of the firm.

H. D. Allan has been appointed Vice-President and General Manager of Worthington (Canada) Ltd. of Brantford, Ontario.

William H. Larkin recently retired as Assistant Executive Secretary of the New York State Water Pollution Control Board after 31 years of service. He has accepted a two-year assignment with ICA in Iran.

Edward H. Bryan has joined the faculty of Duke University as Associate Professor of Civil Engineering.

The Public Health Service has started a six-year anti-pollution study of the Great Lakes Basin-Illinois waterway. **William Q. Kehr** is the project director.

Ripple and Howe, Inc. have moved to 2747 Zuni Street, Denver 11, Colorado.

Smith & Loveless, Lenexa, Kansas, has begun manufacturing operations in Canada with the acquisition of a plant at Oakville, Ontario.

Morrison B. Cunningham, Director of Public Works at Oklahoma City, Oklahoma, was awarded a citation of appreciation by the city managers on the 40th anniversary of his employment with the city.

James B. Coulter is now Chief, Water Projects Section, Technical Services Branch, Division of Water Supply and Pollution Control, with the Public Health Service in Washington, D. C.

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Varec engineers designed a double orifice in the pilot flame ring (A). The ring encircles the waste gas nozzle (B)... forms an actual "curtain of flame" that all waste gas must pass through...: and which positively ignites the gas.

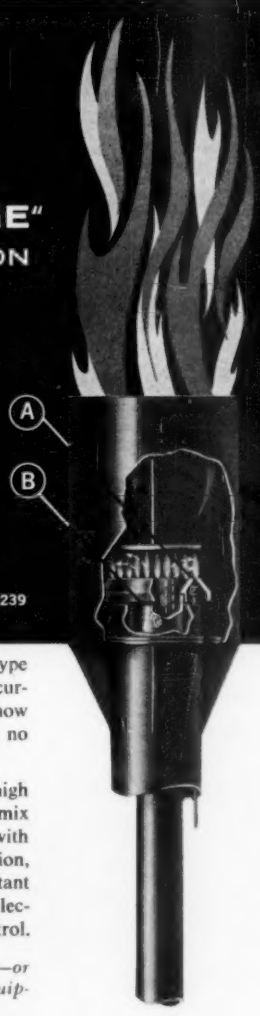

FIG. NO. 239

Varec eliminates ignition problems with its new flare type Fig. No. 239 Waste Gas Burner. The burner's unique "curtain of flame" provides dependable ignition no matter how variable the flow of gas through the burner. There is no loss of pilot flame due to down draft.

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For full information on the Varec Waste Gas Burner—or Varec's complete line of advanced design gas control equipment, write for Catalog S-4, Dept. JWP-1222-3.

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- **SEWER DESIGN AND CONSTRUCTION**

COMPANION VOLUMES IN THE FEDERATION MANUAL SERIES

(Produced jointly with ASCE)

"Sewage Treatment Plant Design," 374 pages of the latest information for those interested in plant design. (WPCF MOP 8).

"Design and Construction of Sanitary and Storm Sewers," the widely used sewer manual containing 283 pages of comprehensive information, including more than 100 illustrations. (WPCF MOP 9).

Each manual is offered to members at $3.50, and to others at $7.00.

Bring your reference library up to date with the addition of these authoritative volumes.

See Publications Page in this issue for other details and convenient order coupon.

WATER POLLUTION CONTROL FEDERATION

4435 Wisconsin Avenue **Washington 16, D. C.**

Proceedings of Member Associations

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

The 34th Annual Meeting of the Ohio Sewage and Industrial Wastes Treatment Conference was held at the Neil House, Columbus, Ohio, June 15–17, 1960.

Registered attendance was 268, with an additional 63 ladies registered. Chairman William Petrich presided at the conference, assisted at the various sessions by Bruce McDill, A. D. Caster, Walter Carroll, and R. N. Simonsen.

The Manufacturers' Forum on Wednesday morning featured papers on incineration of wastewater sludges. The general afternoon session was opened by a paper on the "Review of Columbus Sewerage Progress" by Earl Schoene, city of Columbus. The "History of Pollution Abatement in Ohio" was presented by F. H. Waring, Chief Sanitary Engineer, Ohio Department of Health. Mark Hollis, President, Water Pollution Control Federation, conveyed the Federation greetings to the Conference. At the business session a proposed amendment to the constitution was approved which officially changes the name of the Ohio Conference to "Ohio Water Pollution Control Conference."

The Thursday morning program was divided into concurrent sessions. The sewage session featured a panel discussion on public relations and papers on "Two-Stage Trickling Filter Operation on the Ohio Turnpike," "Training Procedures for Plant Operators," "Electronic Measuring Devices," and

(*Continued on page 653a*)

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Both indexes contain separate listings by author, subject, and geographical categories, along with full cross-referencing. These features make them complete and easily used references.

Send orders to the Federation office; convenient coupon provided on WPCF Publications page elsewhere in JOURNAL.

WATER POLLUTION CONTROL FEDERATION

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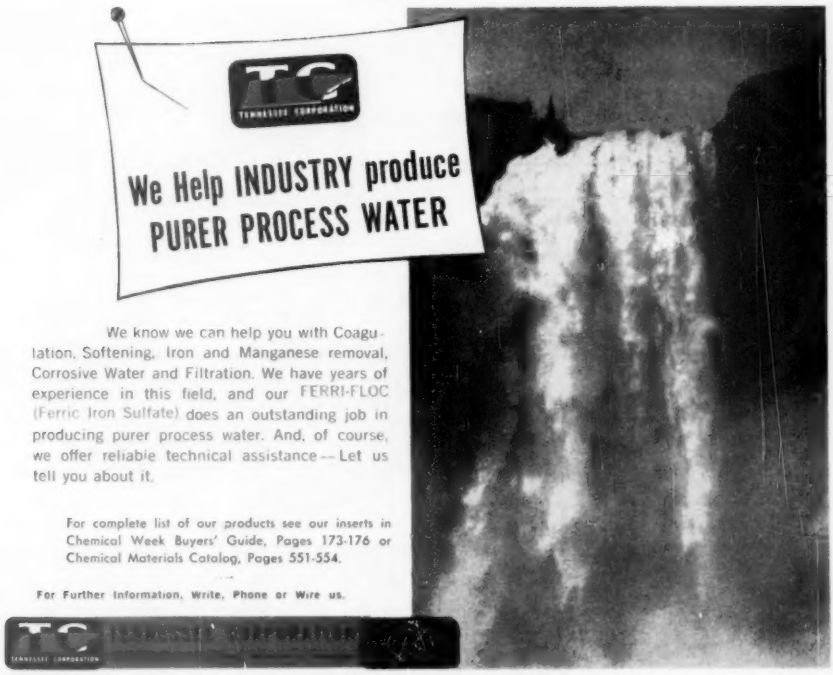
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For complete list of our products see our inserts in Chemical Week Buyers' Guide, Pages 173-176 or Chemical Materials Catalog, Pages 551-554.
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"Aerobic Digestion Plants in Ohio, 1950–1960." The industrial wastes session heard papers on "The Recirculation of Industrial Water," "Industrial Waste Treatment—Steel Plants," and "Meeting the Varied Requirement of Industrial Waste Treatment."

The afternoon session included inspection trips to the Columbus sewage treatment plant, Ternstedt Division of General Motors Corporation waste treatment plant, and Western Electric Company waste treatment plant.

The Conference was concluded with a combined session on Friday morning. Papers heard were on "Problems Relating to Fish Kills," "Traditional Fallacies in Sewer Ordinances," "Treatment of Industrial Wastes in Municipal Sewage Treatment Plants," and "Waste Heat Loadings in Streams."

Following the banquet, the Dean Stewart Award was presented to William Hill, Superintendent, Wadsworth. The F. H. Waring Award went to H. S. Kline, Frigidaire Division, Dayton. The Bedell Award for extraordinary service to the Association was presented to W. D. Sheets, Ohio State University, Columbus, and the Hatfield Award for outstanding plant operation went to James H. Blodgett, Superintendent, Columbus.

Officers elected for 1960–1961 were:

Chairman: A. D. Caster, Cincinnati.
1st Vice-Chairman: R. N. Simonsen, Cleveland.
2nd Vice-Chairman: Max Phillips, Bryan.
Secretary-Treasurer: E. B. Ransom, Columbus.

E. B. Ransom
Secretary-Treasurer

CENTRAL STATES SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 33rd Annual Meeting of the

(*Continued on page 655a*)

WATER POLLUTION CONTROL PRODUCT GUIDE

This list of products and services is offered as an information aid. The list was derived by solicitation from those firms listed. The JOURNAL will make every effort to keep this list current with the help of members and advertisers. All Associate Members and all advertisers for the past year are included. Many of the services and products are advertised in this issue. For an alphabetical listing see Index to Advertisers in back of JOURNAL.

Aerators (*also see* Diffusers, Air)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Infilco Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Penberthy Mfg. Co., Div. of Buffalo-Eclipse Corp.
Permutit Co., Div. of Pfaudler Permutit Inc.
Smith & Loveless
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Yeomans Brothers Co.
Zimmer & Francescon

Agitators
Link-Belt Co.

Air Cleaning Equipment
Westinghouse Electric Corp.

Air Compressors (*also see* Blowers, Compressors, and Fans)
Chicago Pump Co.
Fairbanks, Morse & Co.
Komline-Sanderson Engr. Corp.
Worthington Corp.
Yeomans Brothers Co.

Air Diffusers (*see* Diffusers, Air)

Asbestos Cement Pipe Products
Filtration Equipment Corp.
Industrial Materials Co.
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Ash Handling Equipment
Link-Belt Co.

Automobiles and Trucks
Vulcan Materials Co.

Bearings
Link-Belt Co.

Bins, Storage (*see* Tanks)

Biologists (*see* Directory of Engineers)

Blowers (*also see* Air Compressors, Compressors, and Fans)
Chicago Pump Co.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Sutorbilt Corp.
Yeomans Brothers Co.
Zimmer & Francescon

Boilers
Combustion Engineering, Inc.

Building Maintenance Equipment and Supplies
Homestead Valve Mfg. Co.

Cast Iron Pipe Products
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Industrial Materials Co.
U. S. Pipe & Foundry Co.
R. D. Wood Co.

Cement (*see* Concrete)

Centrifuging Equipment
Bird Machine Co.

Chains
Chain Belt Co.
Link-Belt Co.
Webster Mfg., Inc.

Chemical Feed Equipment
Builders-Providence Div., B-I-F Industries
Eimco Corp.
Fischer & Porter Co.
Graver Water Conditioning Co.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Omega Div., B-I-F Industries
Permutit Co., Div. of Pfaudler Permutit Inc.
Proportioneers Div., B-I-F Industries
Wallace & Tiernan Inc.

Chemicals
Dow Chemical Co.
Fisher Scientific Co.
General Chemical Div., Allied Chemical Corp.
Glenn Chemical Co.
Hach Co.
Tennessee Corp.
Vulcan Materials Co.

Chemists (*see* Directory of Engineers)

Chlorination Equipment
Builders-Providence Div., B-I-F Industries
Everson Mfg. Co.
Fischer & Porter Co.
Graver Water Conditioning Co.
Wallace & Tiernan Inc.
Zimmer & Francescon

Clarifier Equipment (*also see* Sedimentation Equipment)
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Ralph B. Carter Co.
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Lakeside Engineering Corp.
Link-Belt Co.
Permutit Co., Div. of Pfaudler Permutit Co.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Clay Pipe Products
Industrial Materials Co.
National Clay Pipe Mfrs., Inc.
National Sewer Pipe Ltd. (Canada)
Robinson Clay Product Co.
Wedge-Lock Clay Pipe Mfrs., Inc.

Coatings and Linings (Pipe and Tank)
Amercoat Corp.
Centriline Corp.
Corrosion Control Co., Inc.
Inertol Co., Inc.
Koppers Co., Inc.
National Water Main Cleaning Co.
Perry-Austen Mfg. Co.
Stebbins Engr. & Mfg. Co.
Vulcan Materials Co.

Comminutors (*also see* Shredders and Grinders)
Alpha Ltd. (Switzerland)
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Chicago Pump Co.
Dorr-Oliver Inc.
Gruendler Crusher & Pulverizer Co.
Infilco Inc.
Jeffrey Mfg. Co.
Smith & Loveless
Walker Process Equipment Inc.
Worthington Corp.

Compressors
Chicago Pump Co.
Fairbanks, Morse & Co.
Komline-Sanderson Engr. Corp.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Worthington Corp.
Yeomans Brothers Co.

Computers
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.

Concentrators (*see* Sludge Concentrators)

Concrete
Portland Cement Assn.
Vulcan Materials Co.

Concrete Pipe Products
American Concrete Pressure Pipe Assn.
American-Marietta Co.
Gray Concrete Pipe Co., Inc.
Industrial Materials Co.
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Portland Cement Assn.
Price Bros. Co.
Vulcan Materials Co.

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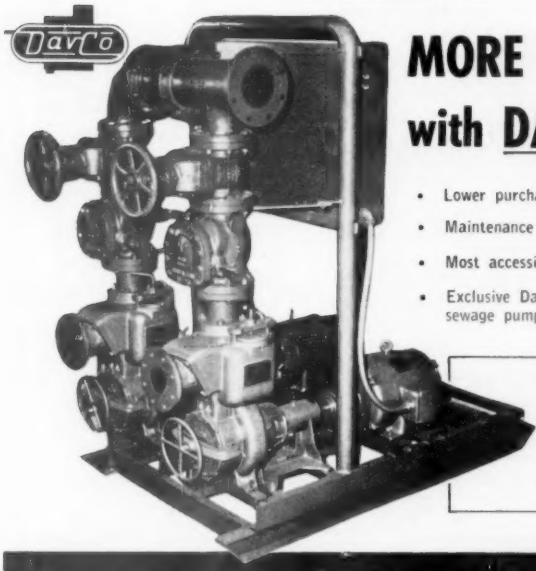
Eimco Corp.
Worthington Corp.



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Central States Sewage and Industrial Wastes Association was held in conjunction with the Conference of Wisconsin Sewage Works Operators at the Hotel Loraine, Madison, Wis., June 15–17, 1960. Registration totaled about 190, including 45 ladies.

The broad-based technical program was well received and included these presentations:

"Review of Advancements in Sewage Treatment," by Richard S. Nelle, Principal Sanitary Engineer, Illinois Department of Public Health, Springfield, Ill.

"Determining Rates of Flow in Sewers Using the Calcozine Red BX Dye Method," by James J. Anderson, Sanitary Engineer, King, Duvall, Anderson & Associates, St. Paul, Minn.

"Effect of Organic Solvents from Pharmaceutical Industry on Biological Filters," by Alfred T. Wallace and Gerald W. Lawton, University of Wisconsin, Madison, Wis.

"Industrial Wastes Control in Milwaukee Metropolitan Sewerage District," by Lawrence A. Ernest, Engineer, Milwaukee Sewerage Commission, Milwaukee, Wis.

"Behavior of Activated Sludge," by John P. Lawler, Research Assistant, and Gerard A. Rohlich, Professor of Sanitary Engineering, University of Wisconsin, Madison, Wis.

"What is Good Plant Operation?" by A. Paul Troemper, District Engineer, Springfield Sanitary District, Springfield, Ill.

"Small Plant Operation and Problems," by Philip S. Davy, Consulting Engineer, La Crosse, Wis.

"Aerobic Digestion of Solids," by Douglas E. Dreier, Chief Engineer, Walker Process, Inc., Aurora, Ill.; Gerald Lawton and Gerard A. Rohlich, University of Wisconsin, Madison, Wis.

Federation affairs were discussed by Past-President William D. Hatfield.

(*Continued on page 657a*)

Controls (*also see* Instruments, Recording and Control)
Builders-Providence Div., B-I-F Industries
Burgess-Manning Co., Penn Instruments Div.
Chicago Pump Co.
Fischer & Porter Co.
Foxboro Co.
General Electric Co.
Homestead Valve & Meter Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.
Ohmart Corp.
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Rockwell Mfg. Co.
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Worthington Corp.

Conveyors
American Well Works
Chain Belt Co.
Chicago Pump Co.
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Corrosion Protection
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Corrosion Control Co., Inc.
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Diffusers, Air (*also see* Aerators)
Alpha Ltd. (Switzerland)
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Penberthy Mfg. Co., Div. of Buffalo-Eclipse Corp.
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Diffusers, Gas (*also see* Aerators)
American Well Works
Carborundum Co.
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Gorman-Rupp Co.
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Infilco Inc.
Jeffrey Mfg. Co.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
A. O. Smith Corp.
Smith & Loveless
Vapor Recovery Systems Co.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Distributors, Rotary
Alpha Ltd. (Switzerland)
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Eimco Corp.
Infilco Inc.
Lakeside Engineering Corp.
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Pacific Flush Tank Co.
Smith & Loveless
Walker Process Equipment Inc.
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Dryers
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Combustion Engineering, Inc.
Eimco Corp.
Hardinge Co., Inc.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Nichols Engr. & Research Corp.
Stuart Corp.

Ejectors
Komline-Sanderson Engr. Corp.
Smith & Loveless
Tex-Vit Supply Co.
Yeomans Brothers Co.

Engineers (*see* Directory of Engineers)

Engines (Sludge Gas and Petroleum Fuels)
Climax Engine Mfg. Co.
Fairbanks, Morse & Co.
Waukesha Motor Co.
Worthington Corp.

Fans (*also see* Air Compressors, Blowers, and Compressors)
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Lakeside Engineering Corp.
Westinghouse Electric Corp.

Filter Equipment, Trickling
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Dorr-Oliver Inc.
Dow Chemical Co.
Eimco Corp.
Filtration Equipment Corp.
Industrial Materials Co.
Infilco Inc.
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Lakeside Engineering Corp.
Nichols Engr. & Research Corp.
Pacific Flush Tank Co.
Smith & Loveless
Trickling Filter Floor Inst.
Walker Process Equipment Inc.
Yeomans Brothers Co.
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Filter Materials
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Filtration Equipment Corp.
Glenn Chemical Co.
Graver Water Conditioning Co.
Industrial Materials Co.
Johns-Manville Sales Corp.
Vulcan Materials Co.

Filters, Diatomaceous Earth
Graver Water Conditioning Co.
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Filters, Vacuum (*also see* Vacuum Filters)
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Eimco Corp.
Proportioneers Div., B-I-F Industries

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Ralph B. Carter Co.
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
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Infilco Inc.
Jeffrey Mfg. Co.
Lakeside Engineering Corp.
Link-Belt Co.
Stuart Corp.
Walker Process Equipment Inc.
Webster Mfg., Inc.
Zimmer & Francescon

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Eimco Corp.
Graver Water Conditioning Co.
Komline-Sanderson Engr. Corp.
Yeomans Brothers Co.

Flow Measurement
Burgess-Manning Co., Penn Instruments Div.
Filtration Equipment Corp.

Gas Control Equipment
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Burgess-Manning Co., Penn Instruments Div.
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Foxboro Co.
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Gas Diffusers (*see* Diffusers, Gas)

Gas Holders, Boilers, and Appurtenances
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Johns-Manville Sales Corp.
Pittsburgh-Des Moines Steel Co.
Walker Process Equipment Inc.

Gaskets
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Gates
Armco Drainage & Metal Products, Inc.
Filtration Equipment Corp.
Industrial Materials Co.
Snow Gates & Valves, Inc.
Webster Mfg., Inc.

Generators
Climax Engine Mfg. Co.
Fairbanks, Morse & Co.
General Electric Co.
Westinghouse Electric Corp.
Worthington Corp.

Grinders (*also see* Shredders and Grinders)
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Dorr-Oliver Inc.
Gruendler Crusher & Pulverizer Co.
Jeffrey Mfg. Co.
Yeomans Brothers Co.

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Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
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SANITARY ENGINEER

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Position requires extensive experience in operation and maintenance of industrial waste and sanitary sewage facilities. Will perform in staff capacity in surveillance of maintenance and operation of sanitary facilities at installations located in the U. S. and overseas. Requires up to ⅓ to ½ of the time in travel status, with transportation mostly by air. Positions are located at Headquarters, Air Materiel Command, Wright-Patterson AF Base (near Dayton), Ohio. Starting salary: $8955.00 per year. Inquiries should be sent to Employment Office, Building 70, Area C,

WRIGHT-PATTERSON
AIR FORCE BASE, OHIO

Dr. Hatfield also presented the Hatfield Award for outstanding achievement in the field of operation to Frank I. Vilen, Superintendent, Kenosha, Wis., and the Bedell Award for extraordinary service to the Association to Kerwin L. Mick, Chief Engineer and Superintendent, Minneapolis-St. Paul Sanitary District, St. Paul, Minn.

At the business session these officers were elected for 1960–61:

President: Walter A. Sperry, Aurora, Ill.

1st Vice-President: Thomas T. Hay, Racine, Wis.

2nd Vice-President: John C. Sager, Minneapolis, Minn.

Director: H. G. Rogers, Minneapolis, Minn.

Secretary-Treasurer: S. E. Linsley, St. Paul, Minn.

S. E. Linsley
Secretary-Treasurer

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Sewage treatment plant operator to be responsible for the operation of a small biological or secondary type sewage treatment plant with trickling filters, primary and secondary sedimentation and contact tanks, heated sludge digesters, and sludge drying beds, located in central New Jersey.

Previous experience in this type of plant operation required, must qualify as Class B operator. Salary open—depending on qualifications.

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Dorr-Oliver Inc.
Eimco Corp.
General Electric Co.
Infilco Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Walker Process Equipment Inc.

Incinerators
Combustion Engineering, Inc.
Morse Boulger, Inc.
Nichols Engr. & Research Corp.
Pittsburgh-Des Moines Steel Co.
Walker Process Equipment Inc.
Zimmerman Process Div. of Sterling Drug Inc.

Insect Control
Glenn Chemical Co.
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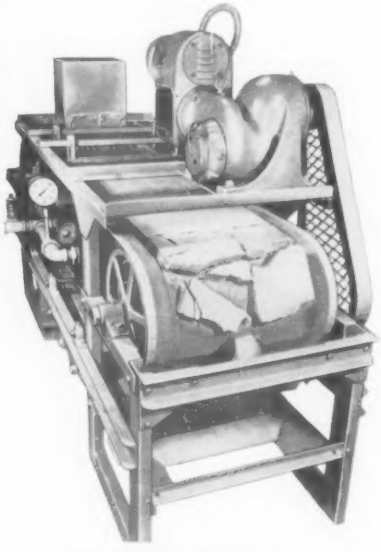

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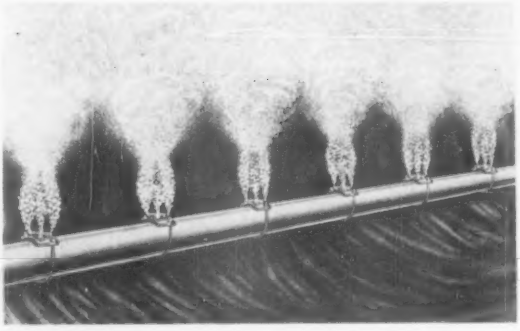

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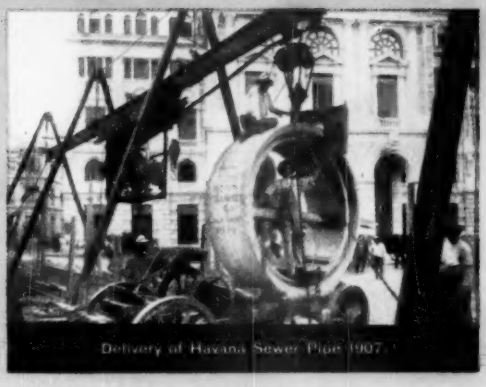

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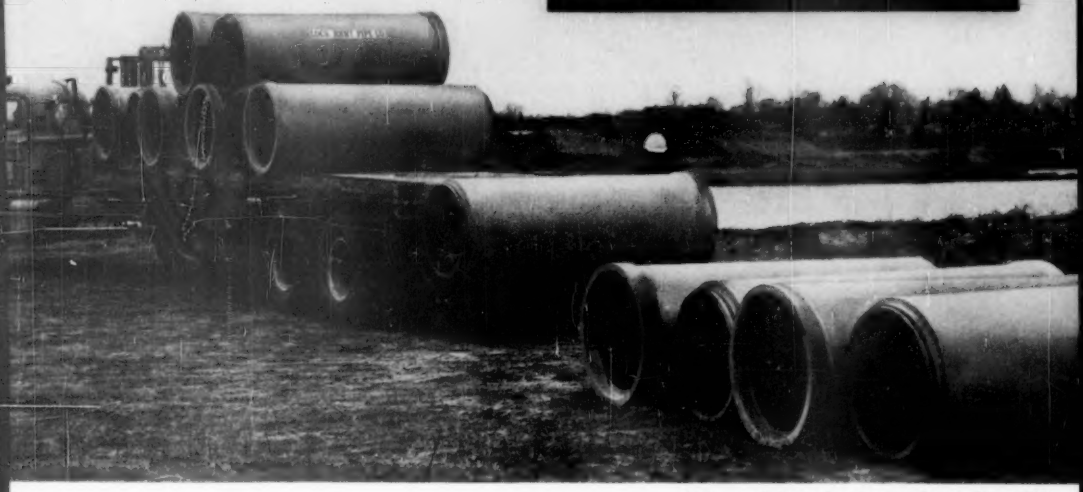

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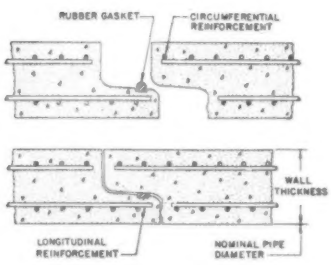

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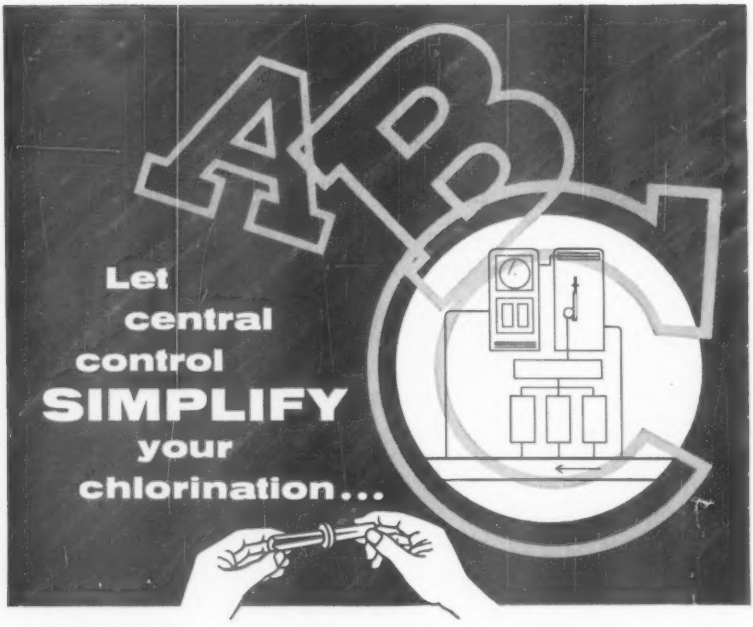

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